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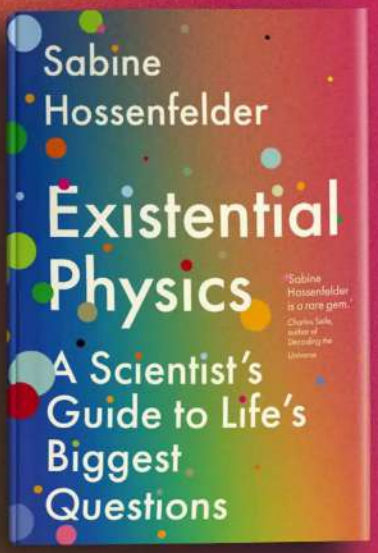

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Lawrence Krauss, theoretical physicist and bestselling author

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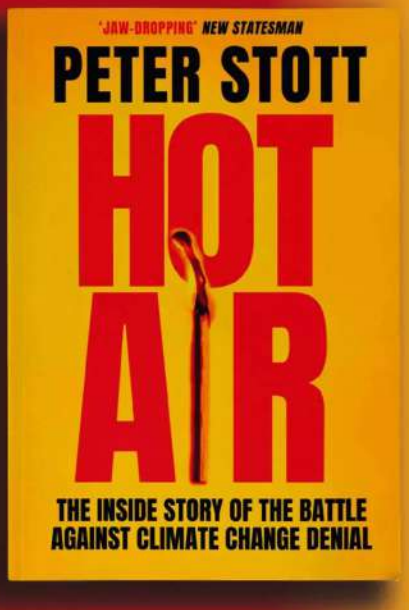

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The real story behind #climategate

Confronting the fossil fuel lobby

How governments concealed the truth

'A deep insight into the nasty, iniquitous, and nefarious tactics used to deny the reality of climate change.'

PROFESSOR MARK MASLIN,
AUTHOR OF *HOW TO SAVE OUR PLANET*

How high can an insect fly? →p79

FROM THE EDITOR

It's fair to say that in the West we have an unhealthy relationship with fat. In the UK, before the pandemic, the NHS reported that 28 per cent of adults in England were classified as obese. Fourteen per cent of children aged four to five fall in the same bracket. And these figures look to be climbing.

The causes for this are complex and tangled. Your genetics, how much you earn and how little you sleep can all help a scientist predict how much you might weigh. Add to that cocktail the availability of food, as well as the way it's marketed and sold to us, and it becomes clear that resisting the bad stuff takes a Herculean effort.

At the same time, fat is also demonised. Both traditional and social media seem to have a pathological obsession with chimeric body standards that change year after year. Meanwhile, health influencers, who know that those of us who are overweight want to change, bombard us with conflicting messages about our weight and our diets. Some will tell you that low-fat, low-calorie (and low joy) meals are the only way to shed some pounds. Others suggest you eat mostly fat, while ditching the carbs. It can feel like a dizzying merry-go-round.

So, with all the mixed messaging and noise around the subject, we thought it was worth asking biologist Tom Ireland to be the voice of sanity and explore what fat actually does in the body. Over on p70 he explains the difference between good and bad fats, why we need fat and why a balanced diet with moderate exercise is the sensible way to keep your body happy.

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

Unvaccinated
Hannah Fry meets a group of people who have so far refused the COVID-19 vaccine, and sees whether the science can change their minds.
Available on iPlayer

The Curious Cases Of Rutherford & Fry
The scientific sleuths return for a new series. In the first episode, they grapple with the psychology of attention – how you can grab it and lose it.
BBC Radio 4
Starts 16 Aug, 11am
Also available on BBC Sounds

The Engineers: The Future Of Cars
Engineers at the cutting-edge of car design explore what the future looks like on four wheels. Kevin Fong hosts this panel discussion, held at the Science Museum.
BBC World Service and BBC Sounds

CONTRIBUTORS

DR RADHA MODGIL
Radha is the latest addition to our new roster of columnists. As a GP and BBC radio presenter, she'll be separating the facts from the fads in the world of health and wellbeing research. →p30

PROF ADAM HART
Is rewilding just a fashionable trend? Adam, an entomologist and conservation expert, shines a light on the less glamorous side of protecting nature. →p42

BEN HOARE
We aren't the only species that builds structures. Ben, a wildlife writer and self-described "nature nerd", steps into the incredible world of animal architecture. →p54

IAN TAYLOR
We could all do with an extra bit of shuteye. Science and health writer Ian gives you all the reasons you need to find a dark, quiet place and just close your eyes for a minute. →p62

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"SOME STUDIES HAVE INDICATED THAT EXERCISING IN A GROUP LOWERS STRESS LEVELS COMPARED TO INDIVIDUAL EXERCISE"

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EYE OPENER

Gently does it

ESA'S ESTEC TEST CENTRE,
THE NETHERLANDS

At the largest satellite test facility in Europe, engineers have successfully unfolded this 11-metre, five-panel solar wing. It's part of ESA's EarthCARE (Cloud, Aerosol and Radiation Explorer) satellite mission, which aims to help us better understand how Earth's atmosphere functions as a system, to give us more reliable climate predictions and better weather forecasts.

Using an atmospheric LIDAR (which uses lasers to calculate distances) and a cloud-profiling radar, EarthCARE will construct vertical profiles of clouds and aerosols, while a multispectral imager will distinguish between the different cloud types. The satellite will also measure reflected radiation at the top of the atmosphere. All this will allow scientists to address one of the biggest mysteries in atmospheric science: what role do clouds (and aerosols) play in the climate system?

Orbiting the Earth at an altitude of 393km, this wing will be stretched out behind the satellite, like a tail. It's expected to launch in 2023.

ESA

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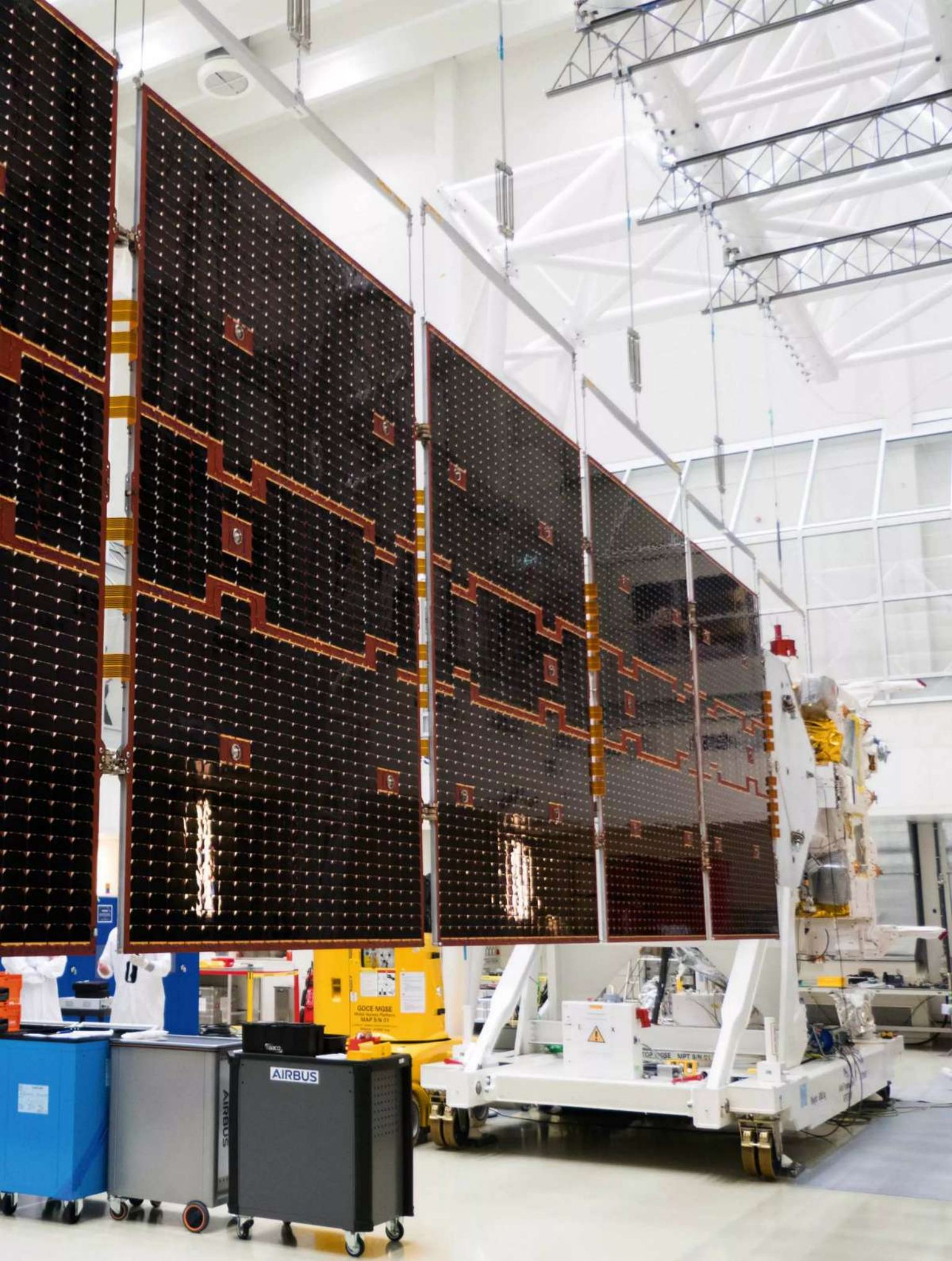
AIRBUS
AIRBUS

EYE OPENER

Hit the dirt

KENNEDY SPACE CENTER,
FLORIDA, USA

Why on Earth would NASA want to buy over 100 tonnes of dirt from a quarry in Arizona?

Well, it turns out that this particular dirt is a great substitute for the material you'd find on the surface of the Moon, called lunar regolith. As such, NASA has collected and stored this dirt in its Granular Mechanics and Regolith Operations facility (aka 'Big Bin'), a climate-controlled chamber for testing equipment bound for the lunar surface.

Inside Big Bin, engineers are testing the Regolith Advanced Surface Systems Operations Robot (RASSOR), which is being developed to collect samples of lunar regolith. It's hoped that this regolith could be mixed with a polymer, made from astronauts' urine, to create 'polymer composite concrete'. This can be made into a strong, carbon-fibre-like material that could be used in a 3D printer to construct lunar habitats.

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EYE OPENER

Coiffured crustacean

DENMARK, WESTERN AUSTRALIA

No, this isn't a tribble from *Star Trek*. This fuzzball with the magnificent coiffure is actually a new species of sponge crab.

Named after the ship that carried Charles Darwin on his voyage around the world, the *Lamarckdromia beagle* was discovered after washing up on a beach in Western Australia. Its shaggy, unkempt appearance is thanks to a tangled mass of setae. These 'hairs' are an extension of the crab's exoskeleton and are a form of camouflage, helping to disguise it from potential threats. In other species of sponge crab, the ends of the hairs are hooked, enabling them to latch on to living sponges to help the crabs hide. For *L. beagle,* however, the sponge simply sits on top of its 'hair'. Worn like a hat, this accessory makes the crustacean look like nothing more than a moving sponge when seen by predators passing overhead.

This one is a female and, if you look closely, you'll see two beady eyes peeking out from behind the fuzz.

COLIN L MCLAY

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Accessible cities, please

Your interesting article on future cities (July, p62) praises the idea of 15-minute cities, where the idea is that all shopping and entertainment should be within a 15-minute walk or cycle trip. But wouldn't this disadvantage a significant part of the population? Estimates for the UK show that by 2030, six million people over 65 will have a long-term illness or disability. These people cannot walk or cycle significant distances, and are unlikely to have the balance for an electric scooter. Without door-to-door transport, these people will be totally isolated. And then there are builders, plumbers and electricians who bring their supplies and tools with them and can hardly walk or use a bicycle. And anyone relying upon a delivery of large items like sofas and electric goods needs delivery to the door. Cities have to accept that there is a fundamental need for door-to-door transport (which can be made electric) alongside cycling or walking, or the city will fail many of its residents.

Dr Peter Stokes, Kent

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a set of **Edifier TWS330 NB earbuds**. These water-resistant earbuds will see you through a sweaty workout or a rainy commute, and are kitted out with noise-cancelling tech to create an immersive listening experience. Plus, they have quick-charging capability, with 10 minutes of charge offering 60 minutes of listening time. **edifier.com**

Past times

I was reading Dr Katie Mack's article about the James Webb Space Telescope (June, p30), and my question is, where does the past begin when it comes to travelling through space? For example, is Voyager's location, 14 billion miles from Earth, still considered to be in the 'now' or our present time? If so, at what stage in its outward journey through space will it begin to enter into 'the past'?

Tony Jackson, Cornwall

Everything we see is in our past! Currently, when we receive a signal from Voyager 1, we're hearing from it as it was more than 21 hours in the past. And when we look at the Sun we're seeing it as it was about eight minutes ago, and even if you look at something across the room you're seeing it as it was several nanoseconds ago. In a cosmological sense, because of relativity, there's no way to define 'now' that's universal – it's necessarily dependent on where you are and what you're doing.

Dr Katie Mack, astrophysicist

Patrick Salmond snapped these noctilucent clouds

"ALL ANIMALS OUTSIDE OF HUMANS ARE NAPPERS. IT'S ALMOST LIKE THE NAPPERS ARE THE ONES THAT ARE MORE NATURALISTIC"

PROF SARA MEDNICK, P62

Is Voyager in the 'now' or in the past?

Noctilucent clouds

I just read Pete Lawrence's article about noctilucent clouds (June, p80). I thought you might be interested to see a couple of photos I took on a flight back from Mexico on Friday morning. Earlier in the flight we also saw the aurora borealis. Enjoy!

Patrick Salmond, via email

Can aliens see our future?

I was reading the article by Dr Katie Mack (June, p30) about the new telescope that will enable us to peer back in time with more clarity, and it made me think. We are able to peer back in time to galaxies forming 10 billion years ago because inflation meant that parts of the Universe grew faster than light speed, meaning the light from earlier objects is still catching up with us. If that is correct, then surely there are possible life forms that are even further out from us looking back on us potentially billions of years in the past. This would mean that if they had the technology to send us information, they could tell us our future. Is that an accurate assumption or have I overlooked a fundamental restriction to that being possible?

Stuart Young, via email

It's just a property of relativity in the Universe, not inflation or anything moving faster than light, that means that when we see distant objects, we're seeing things as they were in the past. Relativity means that everything we see is in the past. Wherever you are, you're getting an outdated view of what you're seeing, because the light that was emitted from the thing you're looking at takes time to reach you. So by the time a signal reaches you, time has passed for whatever sent it, and your information is already out of date. That doesn't give us any option for seeing the future.

Dr Katie Mack, astrophysicist

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DISCOVERIES

"My wife is often saying I'm hangry, but I didn't think being hangry was real"

Prof Viren Swami **p23**

EVOLUTION

DO YOU TAKE MILK?

How lactose tolerance spread in humans **p16**

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Astronomers look back in time to detect the first stars **p22**

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STRIKING GOLD

Beautifully preserved mammoth uncovered by miners in Canada **p24**

Vitamin B6, illustrated here as it would appear under a microscope, seems to have the ability to alleviate anxiety

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EVOLUTION

LACTOSE TOLERANCE EVOLVED IN EUROPEANS THANKS TO FAMINE AND DISEASE

Wide-ranging evolutionary study overturns the long-held idea that the gene for lactose tolerance spread because it allowed dairy-farming humans to consume more milk

Prehistoric Europeans were drinking milk as adults thousands of years before most of them evolved the gene necessary to digest lactose, a study carried out at University College London and the University of Bristol has found.

By poring over DNA and archaeological records dating back 9,000 years, the researchers believe that it was bouts famine and disease periodically killing off the lactose intolerant that drove the protective gene's evolution. This overturns the widely held model that as we began to farm dairy, a novel genetic mutation occurred that allowed some to be lactose tolerant as adults, and from there this became positively selected for and spread throughout the population.

In order to digest lactose, we need to produce an enzyme known as lactase in our guts. Almost all

babies can do this, but the gene to produce lactase switches off in the majority of the global population as they mature into adulthood. The ability to continue producing the enzyme is known as 'lactase persistence' and exists in around one-third of adults in the world, including most of the population of Europe.

When people without the enzyme drink milk, the lactose passes into their large intestine where it can cause cramps, diarrhoea and flatulence – a condition known as lactose intolerance. While this condition is unpleasant, it is rarely fatal. However, its effects can be magnified in those who are malnourished in times of famine or disease, the researchers say. This is what likely drove the evolution of lactose tolerance.

"If you're healthy and lactase non-persistent, and you drink lots of milk, you may experience some discomfort, but you're not going to die because of it," said co-author Prof George Davey Smith of the University of Bristol. "If you're severely malnourished and have diarrhoea, however, then you've got life-threatening problems. When their crops failed, prehistoric people would have been more likely to consume unfermented high-lactose milk – exactly when doing so poses the greatest risk to them."

The discovery depended on several teams working on different pieces of the puzzle. First, researchers led by Prof Richard Evershed from the University of Bristol put together a database of nearly 7,000 organic animal fat residues taken from fragments of pottery from more than 500 archaeological sites to find out where and when people were consuming milk. They discovered that milk was regularly consumed since the earliest dairy farming began around 9,000 years ago, but fluctuated across regions at different time periods.

"When their crops failed, prehistoric people would have been more likely to consume milk"

A second team led by Prof Mark Thomas from University College London looked for the presence of the lactase-persistence genetic variant in the DNA sequences of 1,700 prehistoric Europeans and Asians. They found it first emerged around 5,000 years ago and reached appreciable levels 2,000 years later. They also found that the gene was no more common during periods of greater milk consumption, overturning the long-held view that this was a factor in driving the evolution of lactase persistence.

Finally, Thomas's team compared the presence of the lactase-persistence gene variant in times of suspected famine and disease. They found that the gene became more widespread during these times, indicating that famine and disease played a key part in its evolution.

LEFT The people living on ancient agricultural settlements would have been likely to turn to dairy products in the event of crop failure

ABOVE Humans have been consuming milk and the products that can be made from it for over 9,000 years

SCIENCE PHOTO LIBRARY, GETTY IMAGES

ENGINEERING

TRAINS COULD SUCK CO_2 OUT OF THE AIR AS THEY CROSS THE COUNTRY

A single train fitted with the system could remove thousands of tonnes of carbon every year

Retrofitting direct air capture technology to trains to recover CO_2 could help us get back on track in the fight against climate change, a study carried out at the University of Toronto has suggested.

Direct air capture systems typically extract CO_2 from the atmosphere via a series of chemical reactions that occur as air passes through them. This captured CO_2 can then be stored in a liquid reservoir until it can be sequestered underground in porous rock formations. The technology is already well-established, but stationary, ground-based facilities require a lot of land. This has historically led to residents in the areas near to proposed sites objecting to their construction, the researchers say.

"It's a huge problem because almost everybody wants to fix the climate crisis, but nobody wants to do it in their backyard," said co-author Prof Geoffrey Ozin, director of the solar fuels group at the University of Toronto.

"Rail-based direct air capture cars would not require zoning or building permits and would be transient and generally unseen by the public."

The team's proposed design could be fitted to existing trains and uses a large vent to take in air. This makes it much more efficient than the energy-intensive fan systems used in stationary facilities.

According to their calculations, the researchers say that an average freight train fitted with their system could remove as much as 6,000 tonnes of carbon dioxide per year – an amount comparable to that emitted by 250 medium-sized family cars over their lifespans.

It would also be significantly cheaper to operate than other currently available direct air capture systems and would require far less construction work than stationary facilities, as the rail network is already in place.

"The infrastructure exists," said Ozin. "That's the bottom line. All you need to do is take advantage of what is already available."

Choo choo! The air-cleaning system could be fitted onto freight trains

CO2 RAIL COMPANY, GETTY IMAGES

PSYCHOLOGY

SCIENTISTS MAY HAVE FIGURED OUT HOW TO CONTROL INTRUSIVE THOUGHTS

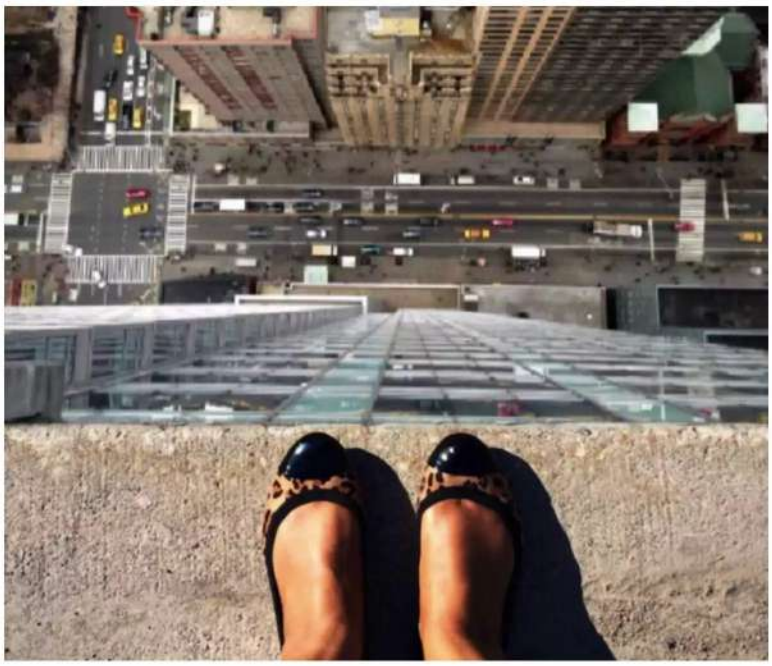
The technique could help with unwanted symptoms of conditions like OCD and anxiety

Most people experience unwanted thoughts from time to time. These internal intrusions can be as harmless as the urge to touch a button that reads 'DO NOT PRESS', or as debilitating as the thought that you can't step outside or you'll be immediately judged – an experience some people with social anxiety might be familiar with.

When we notice an intrusive thought, we will usually react by trying to replace it quickly with something else, something happier. But research from psychologists at the Hebrew University of Jerusalem suggests that distracting ourselves in this reactive way might actually be making the thought stronger. Instead, we should overcome unwanted thoughts using proactive thinking.

For the study, Dr Isaac Fradkin and Dr Eran Eldar asked 80 participants to play a word game. They were shown a series of cue words, and for each they were asked to quickly give an associated word. For example, they may have been shown the cue word 'table', and come up with the response 'chair'.

"Suppressing unwanted thoughts could help reduce them happening"



Each cue was shown five different times throughout the experiment. All 80 people were told they would get paid for their participation, but half the volunteers, called the 'suppression group', were told that they would get an additional bonus only if they did not repeat any words – if they used the response 'chair' for the cue 'table' more than once, they'd lose out. The game's short time limit meant the participants that did best would be the ones who could suppress the thoughts of words they'd already said.

The researchers found that in the participants who were not given the bonus rule, any repeated responses would come faster and faster each time they were said. So, the 'chair' response to the word 'table' was given quicker the second time they saw it compared to the first, and so on. This, the psychologists say, suggested the association in their mind strengthened each time, and the thought took less and less time to arrive in their minds.

People in the suppression group still reported a repeated association. But when they did, they took more time to think of it than the people in the group without the incentive to suppress repeated words. So if a person ensured that an unwanted thought – in this case, the word 'chair' – was not given any strength after its first appearance, they could actually reduce the chance of it popping up in their mind a second time.

The findings suggest that proactively suppressing an unwanted thought could help us reduce them happening in the first place.

"People are usually aware of their attempts to distract themselves from unwanted thoughts, or maybe suppress them in some other way, although they can rarely judge how well these attempts work," said Fradkin. "We tried to examine whether there are additional mechanisms allowing people to reduce the probability of thinking unwanted thoughts in the first place."

PSYCHOLOGY

EATING MARMITE COULD EASE ANXIETY AND DEPRESSION

B vitamins found in the spread may help the brain produce calming neurochemicals

Sorry, haters, here's yet another reason to love Marmite: vitamin B6 – a nutrient found in abundance in the yeast extract – may help to reduce feelings of anxiety and depression, a study carried out by researchers at the University of Reading has found.

The team gathered together a group of nearly 500 volunteers aged between 18 and 58, 265 of whom had self-reported anxiety and 146 had self-reported depression. They then split them into three subgroups. One group was given 100mg doses of vitamin B6 supplements every day for a month, a second received 1mg doses of B12 supplements, and a final group got a placebo.

The researchers also had all participants complete questionnaires designed to assess mood and feelings throughout the study. They found that the participants who took vitamin B6 reported feeling less anxious and depressed after taking the supplements.

While previous studies have suggested that consuming Marmite may help to reduce feelings of anxiety and depression, exactly which nutrients were responsible for the effect remained unclear until now.

The team found that the calming effect was likely due to vitamin B6 increasing the body's production of gamma-aminobutyric acid (GABA), a neurotransmitter that inhibits impulses between nerve cells in the brain.

"The functioning of the brain relies on a delicate balance between the excitatory neurons that carry information around and inhibitory ones, which prevent runaway activity," said lead author Dr David Field, of the University of Reading. "Recent theories have connected mood disorders and some other neuropsychiatric conditions with a disturbance of this balance, often in the direction of raised levels of brain activity. Vitamin B6 helps the body produce a specific chemical messenger that inhibits impulses in the brain, and our study links this calming effect with reduced anxiety among the participants."

Don't worry if you fall into the haters' camp. Vitamin B6 can also be found in tuna, chickpeas and many different fruits and vegetables. However, the doses used in the study are much higher than the amount that could typically be consumed from food, the researchers caution.

"Vitamin B6 helps the body produce a specific chemical messenger that inhibits impulses in the brain"

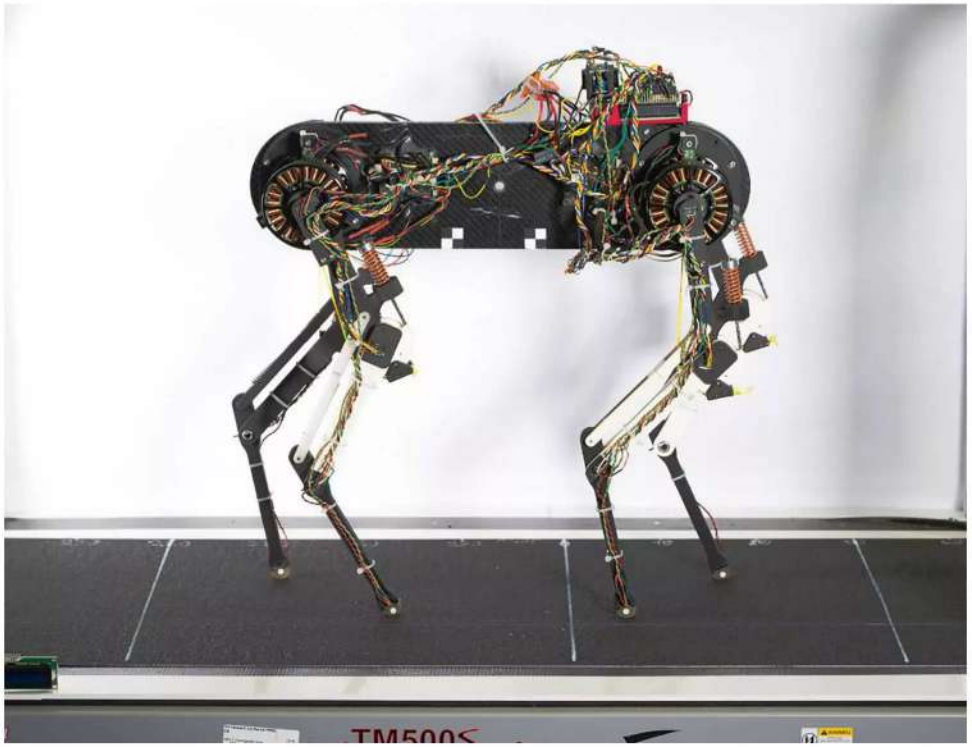
"It is important to acknowledge that this research is at an early stage and the effect of vitamin B6 on anxiety in our study was quite small compared to what you would expect from medication," said Field.

"However, nutrition-based interventions produce far fewer unpleasant side effects than drugs, and so in the future people might prefer them as an intervention.

"Further research is needed to identify other nutrition-based interventions that benefit mental wellbeing, allowing different dietary interventions to be combined in future to provide greater results."

Happy chemicals: crystals of vitamin B6, as viewed under a microscope

SCIENCE PHOTO LIBRARY, FELIX RUPPERT/DYNAMIC LOCOMOTION GROUP/MPI-IS



ROBOTS

ROBOT DOG LEARNS TO WALK BY STUMBLING, JUST LIKE YOUNG ANIMALS IN THE WILD

When this robot gets knocked down, it gets up again

Morti the robot dog taking tentative steps on the treadmill

Morti, a robot dog, has taught itself to walk, just one hour after taking its first step. It learned just like animals in the wild: by tripping and stumbling until it understood how to balance on its limbs.

Morti was developed by researchers at the Max Planck Institute for Intelligent Systems as a way for scientists to closely study how animals learn to walk. With Morti, researchers could measure the forces, torques and muscle power of each limb – something that would've been much more difficult to do in a live organism, said Felix Ruppert, a PhD student and first author of the new study.

In building the Labrador-sized bot, Ruppert and the team first needed to computerise the mechanism by which animals and humans learn to walk.

Walking, like blinking and breathing, are rhythmic tasks because they use the same muscle movements repeated throughout the activity. These tasks aren't coordinated in the brain, but are controlled by networks of neurons, collectively called a Central Pattern Generator (CPG). Our CPG for walking is found in our spinal cord, as this is what controls the muscle contractions in our legs that take us forward, one step at a time. When we trip or stumble over rough terrain, we don't immediately stop walking. This is because the spinal CPG can control our legs' reflexes without needing to check with the brain about how to proceed. Morti therefore had to be given an algorithm that acted like a spinal cord.

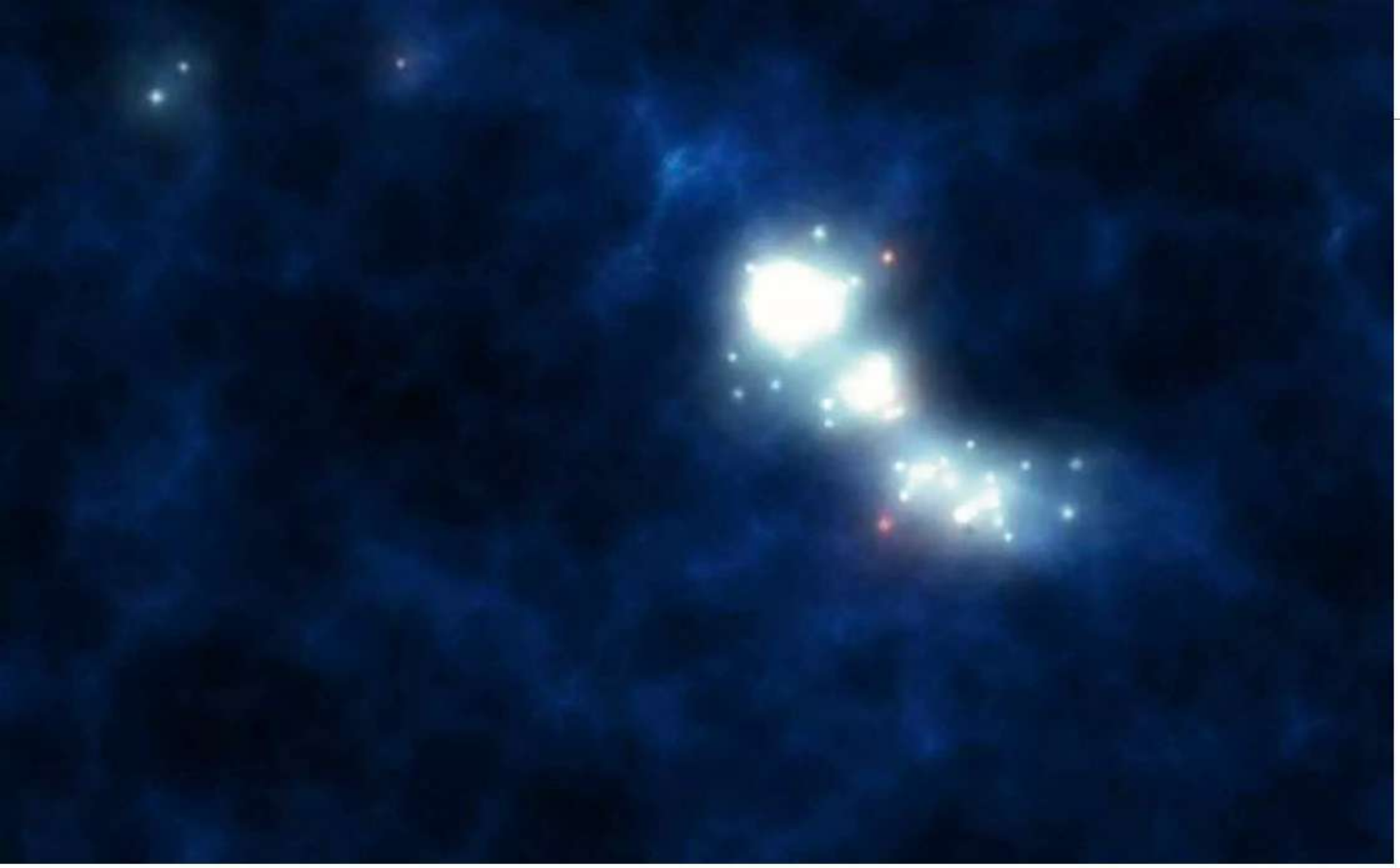
With its basic CPG in place, Morti was put on the treadmill. At this point, Morti had no idea how to walk, nor any way to tell what space it was in or how far to stretch out one leg before putting it down to lift the other. It was as uncoordinated as Bambi.

"The computer produces signals that control the legs' motors, and the robot initially walks and stumbles. Data flows back from the sensors [in the robot's feet] to the virtual spinal cord where sensor and CPG data are compared. If the sensor data does not match the expected data, the learning algorithm changes the walking behaviour until the robot walks well, and without stumbling," said Ruppert.

Compared to other walking bots, which require complicated control systems and several hundred Watts of power, Morti is more efficient, requiring just five Watts to run. As well as advancing robotics in industry, Morti can help answer many of the questions that researchers have about animal movement.

"What drives learning to walk? What is the best placement of muscles and how long should legs and their segments be? And, more broadly, why are animals so good at locomotion [despite] all the neural delays they have – and why have we not been able to reproduce that performance in our robots?

"Bio-inspired robots [like Morti] are a great tool to understand biomechanics and its unanswered questions," Ruppert said.



SPACE

WE COULD SOON PEER THROUGH TIME TO SEE THE FIRST STARS

By analysing primordial clouds of hydrogen, astronomers could detect traces of light from the earliest stars and galaxies

Artist's impression of star formation in the early Universe

Observing the birth of the first stars and galaxies has been a sought-after goal of astronomers for decades. And now a worldwide team has developed a way to observe these ancient stars by looking through the clouds of fog that filled the Universe around 378,000 years after the Big Bang.

The research, part of the REACH (Radio Experiment for the Analysis of Cosmic Hydrogen) experiment, will allow astronomers to observe the earliest stars by studying these primordial hydrogen clouds with a radio telescope.

"At the formation of the first stars, the Universe was mostly empty and composed mostly of hydrogen and helium. Because of gravity, these elements eventually came together and the conditions were right for nuclear fusion, which is what formed the first stars," said lead researcher Dr Eloy de Lera Acedo, from Cambridge's Cavendish Laboratory. "They were surrounded by clouds of so-called neutral hydrogen, which absorb light really well, so it's hard to detect or observe the light behind the clouds directly."

To study the cosmic dawn, they are looking at the 21-centimetre line – a characteristic signal of the presence of hydrogen. It's always the same at the source, which means it's a recognisable signal to look for in your radio telescope data. Therefore, when you point the telescope in a certain direction, you can use this line to distinguish older, more distant hydrogen from the younger, closer stuff. The signal can also tell us about the stars hiding behind the hydrogen, since the light from these stars heats and ionises the hydrogen clouds, which in turn affects this signal. Therefore, by looking at the radio signal from hydrogen, we can tell a lot about these first stars.

They have carried out simulations using multiple antennas to mimic a real observation – when earlier observations have relied on one antenna – to improve the reliability of the data.

"We forgot about traditional design strategies and instead focused on designing a telescope suited to the way we plan to analyse the data – something like an inverse design," said de Lera Acedo. "This could help us measure things from the cosmic dawn and into the epoch of reionisation, when hydrogen in the Universe was reionised."

The team has had to overcome issues, such as distortions being introduced to the signal received. Plus, the elusive signal the team is searching for is expected to be around 100,000 times weaker than other radio signals coming from the sky, such as those from our Galaxy.

With the research method in place, the first observations from the REACH telescope are expected later this year.

NASA/JPL-CALTECH, GETTY IMAGES

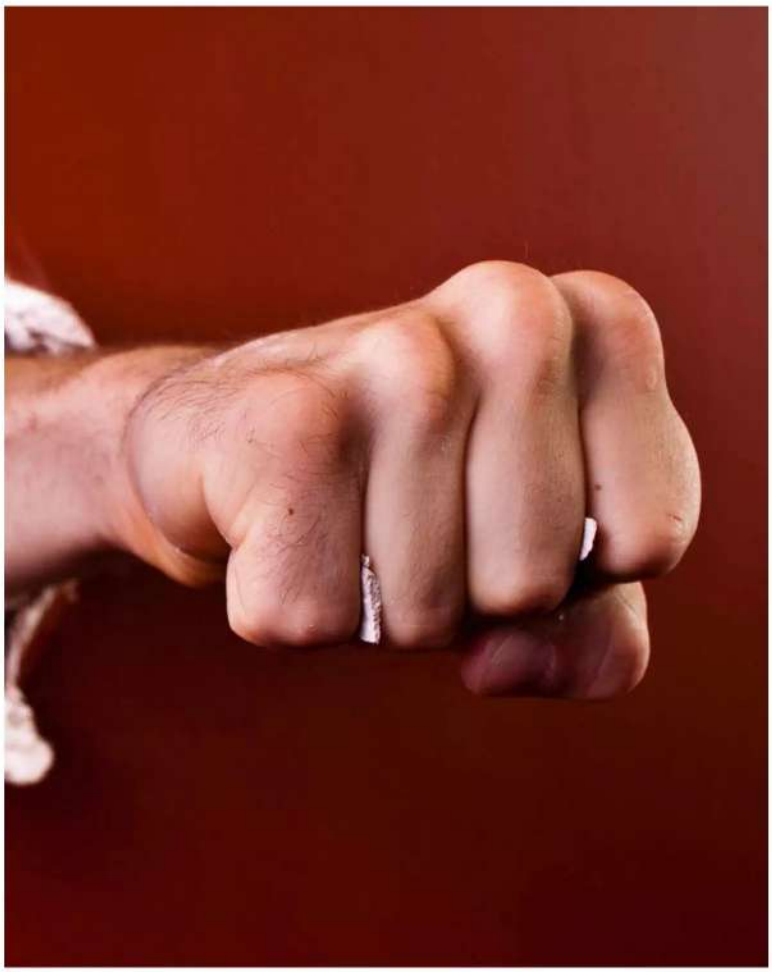
HEALTH

FEELING 'HANGRY' IS REAL, AND THERE'S SCIENCE TO PROVE IT

Scientists tracking people's food intake and emotions have shown that being hungry really can make us angry

It's a common phenomenon: go too long without eating, and you start to feel a little... irritated, to put it politely. Things that might not have bothered you on a full stomach now elicit clenching fists and a pulsing vein on your forehead.

Until now, feeling 'hangry' – angry because you're hungry – has been described in a general, colloquial sense, rather than a scientific one. But when one social psychologist was told they were hangry, they decided to investigate the emotion in more detail (presumably after having a snack).



There are dire consequences when dinner takes too long to arrive

"[The research] came about partly because my wife is often saying that I'm hangry, but I didn't think being hangry was real," said Prof Viren Swami, the study's lead author at Anglia Ruskin University. "But mainly because I'm interested in the impact of hunger and eating on human emotions and behaviours."

Swami and colleagues are the first to study the feeling of hanger specifically, but previous research in lab settings has pointed to links between hunger and mood.

"In some non-human species, food deprivation has been shown to increase motivations to engage in aggression to gain food resources," said Swami. "In humans, hunger has been examined in relation to mood and behavioural difficulties, especially in children, but results have been mixed."

For the new study, 64 adults from central Europe were asked to record their emotions and their hunger levels at several points throughout their day. Over a three-week period, the researchers found that fluctuations in anger, irritability and unpleasantness were strongly linked with hunger.

In fact, hunger was responsible for 34 per cent of the variation in feelings of anger for participants. For feelings of irritability, hunger was 37 per cent responsible.

"In some non-human species, food deprivation increases motivation to engage in aggression"

The exact reason why hunger makes us irritable is still unknown. A number of suggestions have been made – it could be linked to low blood glucose levels, which have been shown in previous experiments to increase impulsiveness and aggression. Or perhaps the lack of food could affect a person's self-control and regulation, which some say triggers negative emotions like anger. But the current study focused on finding the link, not the reason for it being there.

As for those who get hangry, Swami said greater awareness of the feeling itself could reduce the likelihood that hunger results in negative emotions and behaviours in individuals.

"Although our study doesn't present ways to mitigate negative hunger-induced emotions, research suggests that being able to label an emotion can help people to regulate it, such as by recognising that we feel angry simply because we are hungry," said Swami.

PALAEONTOLOGY

MUMMIFIED BABY MAMMOTH FOUND BY CANADIAN MINERS

The immaculately preserved specimen is "one of the most incredible mummified Ice Age animals ever discovered"

For palaeontologists this is better than striking gold: miners working to excavate permafrost in the Yukon in northwestern Canada have unearthed a frozen baby mammoth. Geologists from the Yukon Geological Survey and the University of Calgary say the animal, which has been named Nun cho ga – 'big baby animal' in the language of the Tr'ondëk Hwëch'in, the First Nations people who live in the

GOVERNMENT OF YUKON

region – is female and more than 30,000 years old.

Many Ice Age fossils have been found in the Yukon, but mummified remains with intact skin and hair, as seen on Nun cho ga, are very rare. In fact, she is the best-preserved woolly mammoth ever found in North America. She was discovered by miners working in the Klondike gold fields on Canada's northwest coast, an area that played a key role in the gold rush of the 1890s.

"It has been one of my lifelong dreams to come face-to-face with a real woolly mammoth. That dream came true today," said Yukon government palaeontologist Dr Grant Zazula. "Nun cho ga is beautiful, and one of the most incredible mummified Ice Age animals ever discovered in the world. I am excited to get to know her more."

Tr'ondëk Hwëch'in elders and the government will now work together to preserve and study Nun cho ga.

"This is a remarkable recovery for our First Nation, and we look forward to collaborating with the Yukon government on moving forward with these remains in a way that honours our traditions, culture and laws," said Chief Roberta Joseph. "We are thankful for the elders who have guided us so far and the name they provided. We are committed to respectfully handling Nun cho ga as she has chosen now to reveal herself to all of us."

HORIZONS

KENNETH INGHAM/JIMMY SHAW

BIOLOGY

MICROBES FOUND IN VOLCANIC ENVIRONMENTS COULD HELP REVEAL MORE ABOUT LIFE ON OTHER PLANETS

Researchers studying bacteria in Hawaii's lava caves have discovered intricate communities working together in hostile surroundings

Deep within the lava caves of Hawaii, microbial life thrives. In fact, a recent study has found that the life teeming within the caves is made up almost entirely of unknown species. More surprisingly, the researchers found that the microbial life was structured into complex networks of species that relied on each other. Within these networks were 'hub species', with so many links to other species that if they were removed, it could cause ecological collapse.

HOW DID YOU SEARCH FOR LIFE IN THESE LAVA CAVES?

Dr Rebecca Prescott: We had 70 samples of microbial mats [layers of microbes that live on surfaces] that we looked at from a variety of volcanic environments of different ages. The environments included lava tubes, geothermal caves and steam vents.

In order to identify the microbes, we looked at a gene called the '16S rRNA gene'. It's like a little tag that helps us with identification. We also looked at what microbes were 'hanging out' together, to try to better understand the structure of these communities.

TELL US MORE ABOUT THIS TECHNIQUE.

Dr Stuart Donachie: Prior to 1986, microbiologists could only identify microbes that they'd cultured in the lab. Everything we knew about microbial diversity – meaning how many species there are – was based only on what we could grow in Petri dishes. That gave us a rather narrow view, but it was the best we could do at that time.

In 1986, there was a method developed that involved sequencing [the 16S rRNA gene]. This method is based on extracting as much DNA as possible from the environmental sample, and then making copies of this particular gene. Once this method was applied in the environment, we detected bacteria that had never been seen before.

RP: There are lots of microbes in the environment that have never been cultivated. The majority of them haven't been. We saw a lot of microbial groups [in the volcanic samples] that are what we call 'hub species', meaning that they have a lot of connections to other species of bacteria in these networks. If you were to remove them, you might see a lot of those connections collapse. So they may have important ecological roles.

WHAT DO THESE HUB MICROBES DO?

RP: I can only speculate here. I want to stress that we don't know what their function is. But one example of a hub species would be the Chloroflexi bacteria that we found in the volcanic environments. Some Chloroflexi can photosynthesise at low light levels. They may be able to take carbon into the system. Other organisms around them may not have that ability to photosynthesise in really low light.

SD: Anywhere you get these photosynthesising organisms [such as Chloroflexi], they take inorganic carbon and they make organic molecules from that. But they're kind of like leaky cells – they excrete other biological molecules into the environment. They also die. Their cells break down and it releases the contents of the cells into the environment, and that allows other organisms to grow, which need pre-formed organic molecules.

RP: I study 'quorum sensing', which is bacteria talking to each other through

An example of the thick, green microbial mats hanging inside one of the steam vents in Kīlauea

"Everything we knew about microbial diversity was based only on what we could grow in Petri dishes. That gave us a rather narrow view"

chemicals. When they do this, they can respond to something in the environment as a group.

Part of the reason we wanted to understand these network structures is because we see really high levels of quorum-sensing genes in a lot of caves, and I don't have a good explanation as to why you would see that. So that's another possibility for why you may get a particular organism showing up as a hub species in a network – it could be that it's doing something and then is communicating with others.

COULD THIS TELL US MORE ABOUT MICROBES IN OTHER EXTREME ENVIRONMENTS?

SD: I don't know that we necessarily addressed this in this study, but as a personal observation, [research like this demonstrates] the importance of water. I went into probably 20 caves in the Kīlauea caldera between 2006 and 2009. And some of them are completely dry and a regular temperature. It was a challenge to identify anything biological, except for the plant roots coming through the ceiling.

But in others, the cave was hot and extremely humid. Relative humidity was about, I think, 102 per cent. It's like being in a sauna. There was rainwater from the ground above dripping through the ceiling, then flowing over the walls of the cave and dripping onto the floor. The floor was hot – we put a temperature probe into the ground and it was something like 90°C a couple of inches down.

The water that was coming from the ceiling was dripping onto the floor and being converted into steam. So you get this kind of circulation of rainwater becoming groundwater, and then being converted into steam. And that's where we saw the richest, thick, green microbial mats, which kind of illustrates the importance of water. That's why we always say where there's water, there's life. Life, at least as we know it, needs water. Hence we're looking for liquid water on other planets or any other body, because that's the first thing we know of that's needed for life.

DR REBECCA PRESCOTT
Rebecca is a microbiologist at the University of Hawaii at Mānoa, researching microbial ecology and astrobiology.

DR STUART DONACHIE
Stuart is a microbiologist at the University of Hawaii at Mānoa, examining the biogeochemisty of Hawaiian lava caves.

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From cars that capture carbon to batteries made from trees, here you'll find many reasons to feel hopeful for our future...

Mass plastic clear-up
Ocean Cleanup, a non-profit, has managed to clear 100,000kg of plastic from the Great Pacific Garbage Patch. The company created a giant U-shaped barrier that collects plastic waste carried by the ocean's currents. The company is aiming to clear 90 per cent of the waste in this area by 2040. There are concerns that the device could scoop up sea life along with the junk, but Ocean Cleanup claims to be gathering data to help mitigate the risk.

YEARS TO GO

25

Carbon capture car
A new electric passenger car designed by a team of students captures more CO_2 than it puts out. While driving, air moves through built-in filters where the CO_2 is captured and stored. In the future, the team will look at how to convert this CO_2 into usable energy.

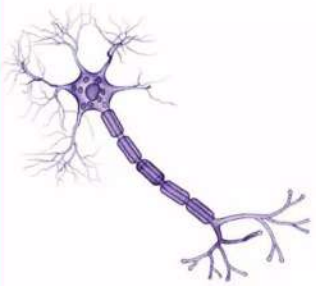
20

Robot toothbrush
Engineers at the University of Pennsylvania have developed a way to brush your teeth using lots of tiny robots. The system uses magnetic fields to manipulate iron oxide nanoparticles to form bristles or floss, and can even release antimicrobials to kill bad bacteria in your mouth.

GETTY IMAGES X5, TU/ECOMOTIVE/EINDHOVEN UNIVERSITY OF TECHNOLOGY, SOLARDUCK, CHRISTOPHER RAMAGE/ARTTIC 2019

Batteries made from trees
A partnership between a paper company and a battery company could result in batteries being created using renewable sources from trees. The team has found a way to turn lignin, a polymer derived from the cell walls of plants, into a hard carbon material for use in batteries. This technology could be used in the future to power cars, the researchers say.

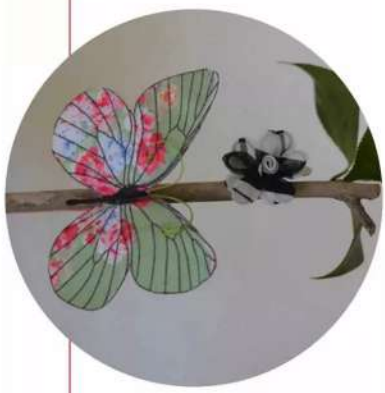
Nerve cooler
Researchers from Northwestern University have created a method of pain relief that could effectively be dialled up or down. The technology uses materials that dissolve in your body, encircling nerves with an evaporative cooler, as low temperatures can numb nerves. The technology is still in its test phases, but it could soon revolutionise the way we deal with pain.



Floating solar 'carpets'
The German energy firm RWE is looking to invest in 'floating solar parks'. These would consist of a huge collection of connected solar panels that would sit on top of the waves like a carpet. The company is already planning to integrate these solar parks with wind and hydroelectric power, creating a hybrid system of renewable energy all from one setup.

10

Animal-to-human heart transplants
The second-ever gene-edited pig heart has been successfully transplanted into a human. Animal-to-human transplants are in the experimental stages and come with a lot of risks. As this technology advances, it offers up the very real opportunity of saving those people in need of emergency transplants.



Muscle vests
Engineers at the University of New South Wales in Australia have created a smart textile that can shape-shift into 3D structures. Most shape-shifting materials rely on slow heating processes, but the team is instead using long fluid-filled hydraulic pumps. They hope to use this technology in assistive clothing, but have demonstrated its ability with shape-shifting fabric butterflies and flowers.

0

Solar tower
The aviation industry is responsible for spitting out a large chunk of global carbon emissions. But a team of researchers from ETH Zurich say they have created a new piece of tech to combat this – a tower capable of creating synthetic kerosene (a jet fuel) using solar radiation, water and carbon dioxide, without the need for carbon-rich fossil fuels.

COMMENT

EXERCISE PILLS: A HARD IDEA TO SWALLOW

A new pill could offer the physical benefits of an active lifestyle, but what about the boost that exercise can give your mental health?

Keep active and get moving are messages we hear a lot of when it comes to wellbeing advice. And with good reason. Exercise is miraculous.

It is proven medically and scientifically that keeping active has a multitude of benefits. People who take part in regular physical activity have a reduced risk of stroke and heart disease, type 2 diabetes, some cancers, dementia, hip fractures and dying early.

And now, researchers from the Baylor College of Medicine, publishing their findings in the journal *Nature*, have found a molecule produced by the body during exercise that can reduce appetite and obesity.

The research team analysed blood samples from mice who had run on a treadmill and found a modified amino acid called Lac-Phe was produced from lactate and phenylalanine. When obese mice on a high-fat diet were then given Lac-Phe, it reduced food intake by approximately 50 per cent over 12 hours, which was totally unrelated to movement or energy expenditure. Next, Lac-Phe was given to mice over 10 days and the researchers found it reduced food intake, body fat and weight, and improved glucose tolerance. High levels of Lac-Phe is also found in racehorses and humans after exercise, perhaps strengthening the idea that this biochemical response is a regulatory system that has always been present in many species.

If we can harness this molecule and put it in pill form, could we, at some point, get all the benefits of exercise from simply taking a tablet? This is an exciting idea, as it may offer a way to improve the health of people who struggle to exercise due to various conditions or illnesses.

As this study demonstrates, in our world there is a lot of focus on the physical health benefits of exercise, but not so much attention on the mental and emotional benefits an active lifestyle can offer. Exercise has an impact on our self-esteem and confidence, our cognition, our sense of purpose, our ability for connection, and our sense of achievement in reaching bespoke and personalised goals.

Exercise is proven to reduce depression and anxiety, and can help us manage negative feelings as well as alleviate symptoms of social withdrawal. It is a tool that we can use to support our mental health and wellbeing.

Cognitive function is also improved through exercise. Research using mice models has found that cardiovascular exercise triggers the creation of new brain cells. Exercise can improve memory and cognitive decline, as well as sparking creativity.

And these benefits start early. There is some evidence that when children get active it can improve their cognition and boost their ability to concentrate. It can help them to perform better academically in some subjects, along with supporting their ability to regulate their emotions.

We have all experienced that sense of personal achievement in gaining a new skill in sports, or reaching a goal we have set ourselves. This is no surprise, as studies have also shown that increased physical activity influences self-esteem directly, and therefore could be considered as a recommendation for people who report low self-confidence. Exercise doesn't have to mean pounding out the miles on a treadmill, either; we can choose the activity we like best, whether that's dancing, swimming, trampolining or walking.

Exercise can help connect us to ourselves and others, which makes it a particularly useful activity in a society such as ours where loneliness is prevalent. Some studies have indicated that exercising in a group lowers stress levels compared to individual exercise, and can significantly improve reported quality of life. Other studies have shown group exercise contributed to expanding communities through mutual support and social connectedness.

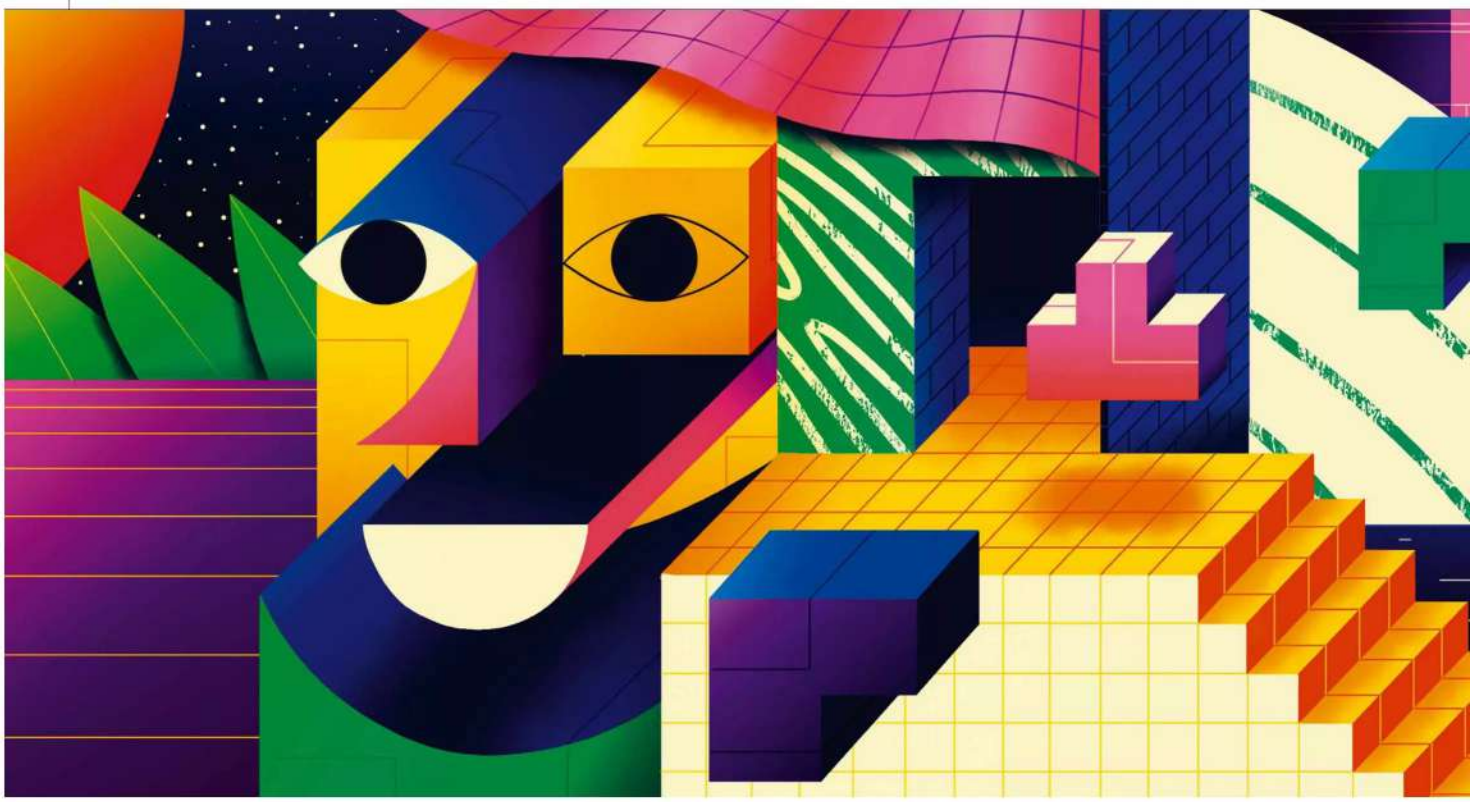
It is perhaps not surprising that many studies report a positive impact on wellbeing and loneliness, when people take part in group activities.

So, although this research into Lac-Phe is exciting, if we do ever manage to achieve all of the physical benefits of exercise in a tablet, it's important to make sure that we don't forget the other benefits that an active lifestyle can offer. Our overall health and wellbeing is made up of physical, mental and emotional elements. These are not mutually exclusive, but rather must exist in a perfect, parallel harmony.

"When obese mice on a high-fat diet were then given Lac-Phe, it reduced food intake by approximately 50 per cent over 12 hours, which was totally unrelated to movement or energy expenditure"

DR RADHA MODGIL
(@DrRadhaModgil)
Radha is an NHS doctor, broadcaster and wellbeing campaigner. She is the medical expert on BBC Radio 1's Life Hacks. *Her first book,* Know Your Own Power *(£14.99, Yellow Kite), is out now.*

ILLUSTRATION: MARIO WAGNER



COMMENT

HOW TO CREATE A VIRTUAL CHILD

Criminal psychologists and computer scientists are using virtual avatars to train people how to interview vulnerable children

DR JULIA SHAW
(@drjuliashaw)
Julia is a psychological scientist at University College London, the author of multiple best-selling books, and the co-host of the hit podcast Bad People *on BBC Sounds.*

Ask a child a question, and you will quickly learn that many of their answers are quite scattered. You ask how their day was, and they respond with a story about how much they like turtles. Try again, perhaps more specific this time, and you might get a curt "yes". Children respond to questions in such literal and lateral ways that there is a whole section of parenting literature that deals with teaching children how to answer questions. But what about asking the right questions?

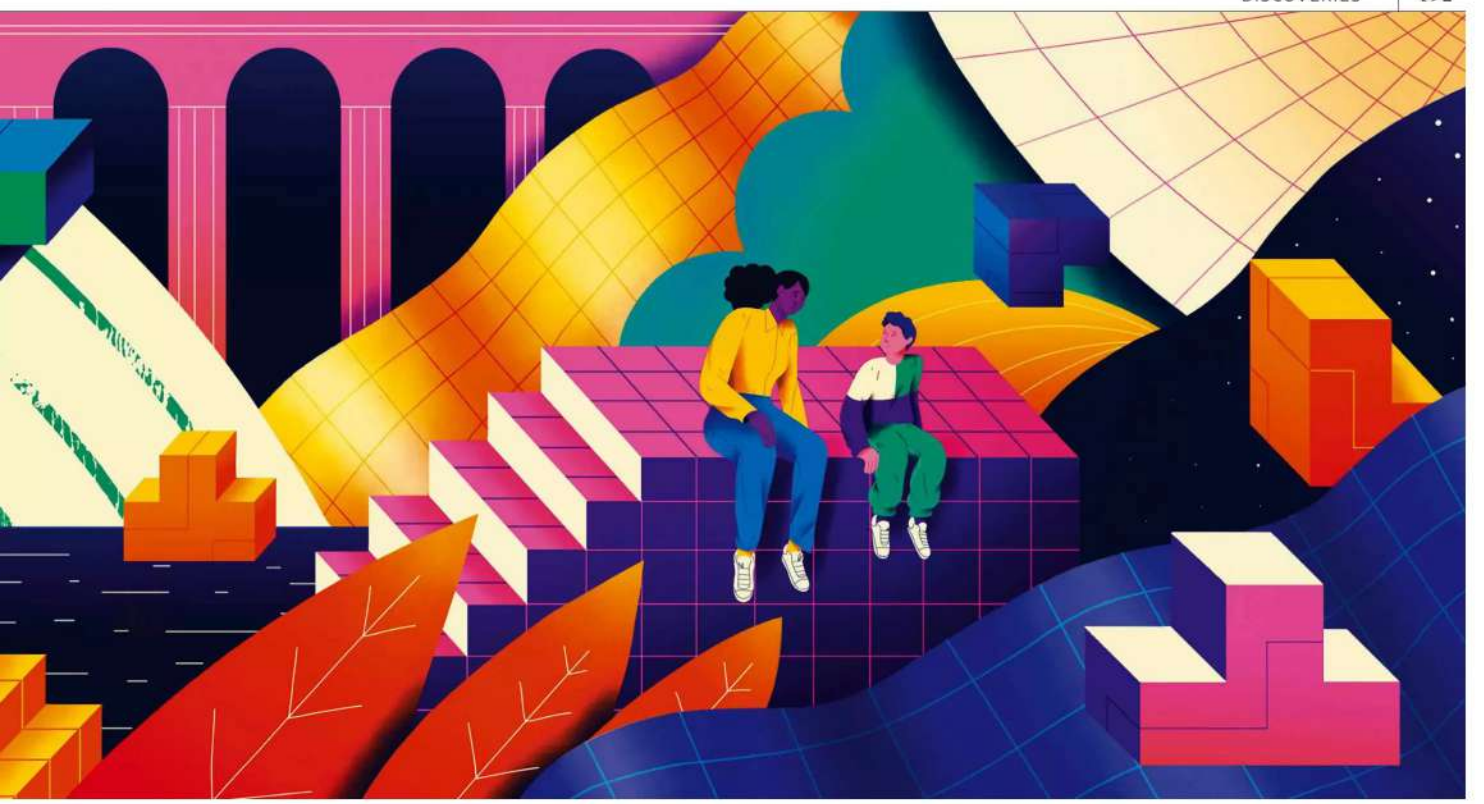
When you are concerned that something bad has happened, those hard-to-get answers become all the more frustrating. They can become a problem for safeguarding children or investigating a crime. Children aren't tiny adults, and this means that teachers, social workers, judges, police, paediatricians and psychologists can all benefit from training on how to interview children. The issue is that training people how to question vulnerable children is no easy task. Interviewing skills are all about learning the evidence-based guidelines, then getting the opportunity to practise and feedback. It's unethical to train on actual children, so courses improvise. Some training courses hire actors to play children. But others are turning to a new approach.

In place of a well-meaning adult pretending to be a child, a simulation could be the next best thing. Doctors use them to train for surgeries, F1 drivers use them whenever they're away from a track. Now, researchers have created digital children where child lookalikes are programmed to have 'memories' and answer questions like real children do. Your task is to figure out if something bad happened to the virtual children.

What exactly these virtual children look like depends on the team. Some are realistic, made to look, move and sound as close to real children as possible by using realistic game characters or deepfakes. But this has led to problems with the 'uncanny valley', which is when something creeps us out because it looks *almost* real but not close enough to be convincing. This has led some researchers to create virtual children that look and sound like game characters instead.

The first vulnerable child avatars were created by a team of Finnish and Italian researchers. In a study the team published in 2014, people interviewed the digital children and the goal was to find out

ILLUSTRATION: CATHAL DUANE



"Virtual children have the potential to revolutionise investigative interview training"

whether they had a 'memory' of something bad. Like in real life, only some of the avatar children were programmed to have 'experienced' something bad.

The researchers accounted for how suggestible children are. For example, if someone asked one of the avatar children the same suggestive question three times, the third time the child would change their answer from 'no' to 'yes'. This is to mimic when children say something that is untrue because of how they have been questioned.

People who were given feedback after each interview got better at asking open questions in a short period of time. They also came to more correct conclusions about whether there were safeguarding concerns. These promising results prompted other teams to try to make their own virtual children. One German team created avatars in virtual reality classrooms. In a VR context it feels like you are sitting across from the child, rather than looking at them on a screen, which can make the interaction more realistic. The virtual children's 'memories' are also based on real cases.

Children need to trust you. They also require reassurance, or they might suddenly clam up. This is something the German researchers have built into their simulations. For the VR children to tell you what happened, you need to start with neutral or positive topics. This is a technique that most people who work with children will know as a way to build rapport. You are also more likely to get useful details if you make reassuring comments.

The newest project to date is by an international team of computer scientists and psychologists. They want to create a standalone AI child. In June 2022, the team explained that they synthesised a talking child avatar from 1,000 transcripts of mock interviews using actors trained to behave like children. This is just for the initial testing, as they plan to train the AI on interviews with actual children soon. It'll be interesting to see what happens when human coders are taken out of the picture. Will an AI child be able to sufficiently mimic a real one?

All this research is so fresh that the tools are not available in mainstream settings. But results so far are promising. Virtual children have the potential to revolutionise investigative interview training. That is, once researchers figure out how to make the avatars less creepy...

BBC SOUNDS
Listen to Dr Julia Shaw on the *Bad People* podcast, available on BBC Sounds.

COMMENT

THE (SQUIRREL'S) GHOST IN THE MACHINE

Why questions about robot sentience can lead to far-reaching conversations about the people we want to be

The news media went wild in June over a report that Google engineer Blake Lemoine believed one of the company's advanced AI systems, LaMDA (Language Model for Dialogue Applications), was sentient. The resulting coverage focused on the definition of sentience and how to tell if a machine has the ability to experience feelings.

LaMDA is a language model developed by Google to power chat platforms. Thanks to training on trillions of words and phrases on the internet, LaMDA's conversational output is incredibly advanced, leaving many previous conversation technologies in the dust.

Lemoine, who was placed on administrative leave and later fired for breaching company confidentiality, published an (edited) transcript of a conversation with the system that included impressive exchanges on emotions, literature and more. In the exchange, LaMDA tells Lemoine "I am aware of my existence" and "I feel happy or sad at times". Except, while LaMDA claims "I want everyone to understand that I am, in fact, a person", it turns out that AI systems are equally enthusiastic to describe other subjective experiences. For example, AI researcher Janelle Shane recently interviewed GPT-3, another advanced large language model, about being a squirrel.

Janelle: Can you tell our readers what it is like being a squirrel?
GPT-3: It is very exciting being a squirrel. I get to run and jump and play all day. I also get to eat a lot of food, which is great.
Janelle: What do you say to people who doubt that you are a squirrel?
GPT-3: I say that they should come and see for themselves. I am a squirrel, and I am very happy being one.

Is a system sentient because it can describe being sentient? What matters more is whether the system is doing what people think it's doing. While LaMDA may display intelligence, it doesn't have experiences or think like a human (or a squirrel). But we have an inherent tendency to project our own experiences onto others, even if the 'other' is not like us. For example, dog owners will project human emotions like guilt onto their pups, despite studies showing that the look on their furry faces is something else entirely.

Even though LaMDA is not sentient according to most people's definitions, the story prompted speculation around advanced AI. How would we know if a language model achieved sentience? Would that create a moral responsibility toward these machines? After all, if we accept that future AI has the ability to suffer, Lemoine's argument that LaMDA needs rights will resonate.

Science fiction stories love to compare robot rights to human rights, but there's a better comparison: animals. Society's treatment of animals doesn't care about their inner worlds at all. Looking at how we view our moral responsibility towards animals, and in particular which animals, shows that the importance the current tech media is giving to 'sentience' doesn't match our society's actions. After all, we already share the planet with sentient beings and we literally eat them.

The most popular philosophical justifications for animal rights are based on intrinsic qualities like the ability to suffer, or consciousness. In practice, those things have barely mattered. Anthrozoologist Hal Herzog explores the depths of our hypocrisy in his book *Some We Love, Some We Hate, Some We Eat*, detailing how our moral consideration of animals is more about fluffy ears, big eyes and cultural mascots than about a creature's ability to feel pain or understand.

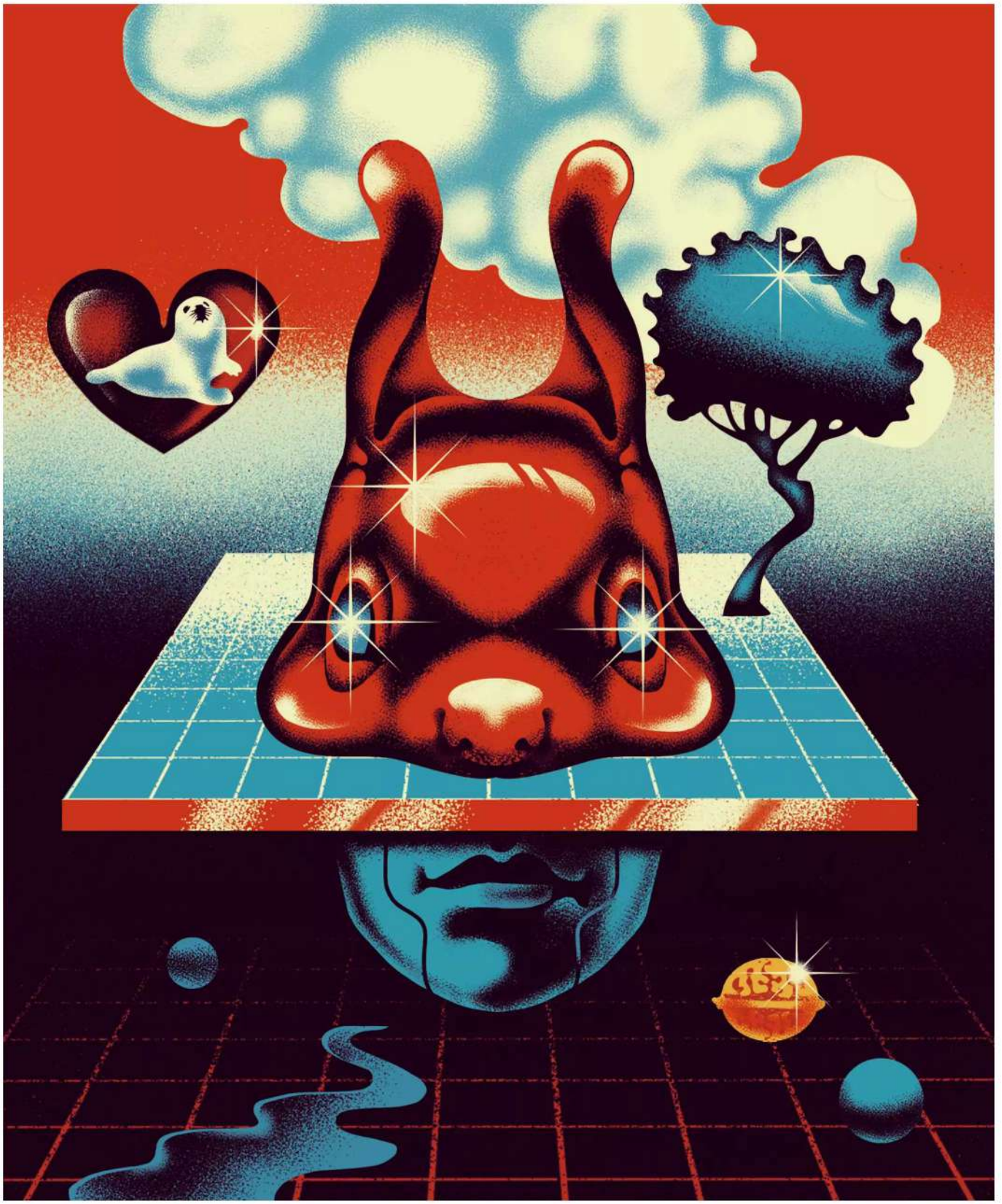
Our conflicted moral behaviour towards animals illustrates how rights discussions are most likely to unfold. As technology becomes more advanced, people will develop more affinity for the robots that appeal to them, whether that's visually (a cute baby seal robot) or intellectually (like LaMDA). Robots that look less adorable or have fewer relatable skills will not meet the threshold. Judging by the pork pie you had for lunch, what matters most in our society is whether people feel for a system, not whether the system itself can feel.

Perhaps AI can prompt a conversation about how sentience doesn't matter to us but should. After all, many of us believe that we care about the experiences of others. This moment could inspire us to grapple with the mismatches between our philosophy and our behaviour, instead of mindlessly living out the default. Conversational AI may not know whether it's a person or a squirrel, but it might help us figure out who we want to be.

"As technology becomes more advanced, people will develop more affinity for the robots that appeal to them, whether that's visually or intellectually"

DR KATE DARLING
(@grok_)
Kate is a researcher at MIT, where she investigates technology and society, and studies human-robot interaction.

ILLUSTRATION: VALENTIN TKACH



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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Money | Dark matter | Rewilding

REVIEW

MONEY: CAN IT BUY YOU HAPPINESS?

We all need enough to cover our basic needs, but beyond that the link between wealth and wellness is less clear

"Once we're 'financially secure', as they say, money can still be rewarding, but its power to make you happy is significantly reduced"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

'Money can't buy you happiness' is either a well-known piece of folk wisdom, or a tired cliché. Is it right, though? Scientifically speaking, the answer is... mixed.

A recent study carried out at the University of Bath has once again looked at the relationship between income and happiness. It seems that, up to a point and within a specific set of circumstances, money *can* buy happiness. But beyond that, the relationship between money and happiness becomes more uncertain.

WHAT MAKES US HAPPY?

At the most fundamental level, the things that make us happy – or at least that provoke a positive response in our brains – are those that satisfy our basic biological needs. We humans, as living organisms, need many things to ensure our survival, such as food, water, air, sleep and security. Our brain recognises these things as being 'biologically significant', so if we obtain them, we experience a sense of reward.

Because the human brain can make intuitive and abstract leaps, it can easily recognise that receiving money means we can now more easily obtain food, water, shelter, etc. This, as a study carried out by the Wellcome Trust in 2007 found, can be both rewarding and motivational, two things that could both be considered to fall under the umbrella of happiness.

However, this doesn't mean 'more money' automatically means 'more happiness'. Money may be recognised by our brains as biologically significant, but there's an upper limit on how rewarding even biologically significant things can be. For example, eating food can often be pleasurable, but at some point you'll be sated, after which point eating more causes actual discomfort. The same goes for drinking, and even for things like shelter and security – build too many barriers around yourself and you can end up feeling isolated and oppressed.

There's also the phenomenon of habituation, where the fundamental parts of our brains learn not to react to things that occur predictably and reliably. As evidenced in a 2011 study carried out by Dr Ruth Krebs at Ghent University, this is why things that are novel, as in surprising and unexpected, are often more rewarding than familiar things.

In many cases, the same thing happens with money. Receiving your regular pay is reassuring, but receiving money unexpectedly, even if it's a far smaller sum, often makes you much happier.

Also, when we actively and tangibly need it for our survival, obtaining money is very rewarding. Once we go beyond that point – once we're 'financially secure', as they say – money can still be rewarding, but its power to make you happy is significantly reduced, and more psychological, experience-based stimuli (travelling, forging new relationships, helping others and so on) have a greater ability to make you happy.

Granted, in the modern world you usually need money to do all those things too. But this ultimately means money's link to happiness is more indirect: it's a means to an end, rather than directly rewarding in its own right.

IS THERE A THRESHOLD AMOUNT OF MONEY THAT CAN MAKE YOU HAPPY – OR UNHAPPY?

That there's a certain cut-off amount of money where it stops making people happy has a lot of implications, particularly in the present day. ➲

We tend to take our weekly or monthly pay cheques as read – yet will be delighted by a £10 scratchcard win

GETTY IMAGES, ALAMY

With much talk of wage stagnation and inflation, and with trials of universal basic income becoming more common, the question of how much money people need to be happy is increasingly salient.

Unfortunately, there can be no easy answer, at least not one that applies to all people equally. This is because the factors that determine how much money is 'enough' for security and happiness are highly subjective, and vary considerably from person to person.

Some people feel they'd be happy for life with surprisingly modest sums, while others don't think they'd ever feel that they had 'enough' money. Studies carried out by researchers at the University of Bath have also found that these significant variations are even more apparent when you compare people from different cultures, suggesting the link between money and happiness is at least as much learned as it is 'innate'. But even within the same capitalist culture, people's ideas about financial security can differ, with people who have ample money sometimes being much less happy than those with far less, because they worry about it more.

CAN TOO MUCH MONEY MAKE US UNHAPPY?

This introduces another factor: money can actually make you unhappy, or reduce happiness in other ways. Studies have shown that being paid to do something you enjoy can make you less motivated to do it, suggesting it actively reduces potential happiness. This would explain why people are often reluctant to turn a hobby into a job, or actively regret doing so.

Also, in our modern world, money is not static. If we have more money than we strictly need, we don't hoard a big pile of gold coins in our spare room like modern-day dragons. Money is fluid, often intangible, and typically ends up being tied up with things like investments, stocks, properties, savings accounts and more. All these things are subject to the whims of politico-economic factors and more, which means the person whose money it is has less control over it and less certainty than if they'd gone for the 'big pile of gold' option. And loss of control and lack of certainty are two reliable sources of stress and unhappiness for the brain.

Ultimately, rather than thinking that money can't buy happiness, it might be better to consider that money can buy you safety and security, and these things make it easier for you to be happy. But there's no direct one-to-one relationship between money and happiness, and how it affects us ultimately depends on who we are and how we've been raised.

by DEAN BURNETT

Dean is a neuroscientist and science writer. He explores happiness in more detail in his book, The Happy Brain *(£9.99, Guardian Faber).*

ANALYSIS

DARK MATTER: IS IT TIME WE GAVE UP LOOKING FOR IT?

After decades of looking for dark matter and coming up short, some researchers say we should take the possibility of a new theory of gravity more seriously

Two cosmic anomalies tell us that something big is missing from our model of the Universe. First, stars in the outer regions of a typical galaxy are orbiting the centre too fast for the galaxy's gravity to hold onto them. By rights, they should fly off into intergalactic space.

GETTY IMAGES

ABOVE
The search for dark matter has preoccupied physicists for decades. Is it time to move on?

The second anomaly is that you are reading these words – that is, galaxies like the Milky Way, and therefore you, exist. According to the standard picture of galaxy formation, regions of the cooling debris of the Big Bang that were slightly denser than average would have had slightly stronger gravity and pulled in material faster, enhancing their gravity so they pulled in matter even faster, and so on. But this process – akin to the rich getting ever richer – could not have built galaxies as big as our Milky Way in the 13.8 billion years that the Universe has existed.

Confronted with these anomalies, most astronomers postulated that the Universe contains about five times as much invisible matter as visible stars and galaxies. It is the extra gravity of such 'dark matter', they claim, that holds onto stars in galaxies and sped up galaxy formation. However, an equally logical possibility is that, on cosmic scales, gravity is stronger than Newton would have predicted.

In 1981, the Israeli physicist Prof Mordechai Milgrom found that the anomalously orbital motion of stars in the outer regions of galaxies could be explained if they were experiencing a stronger form of gravity. This would mean that gravity weakens less quickly with distance than the Newtonian

"An equally logical possibility is that, on cosmic scales, gravity is stronger than Newton would have predicted"

theory of gravity predicts, and 'switches' to this form when the stars are experiencing a particular threshold acceleration towards the centre of their galaxies. Thus was born the hypothesis known today as modified Newtonian dynamics, or MOND.

Stars are always experiencing an acceleration towards the centre of a galaxy. This is called centripetal acceleration. Gravity must provide this acceleration to keep them in orbit. The point is that in MOND, gravity switches to the stronger form at a threshold acceleration of 10^{-10}m/s^2, which is generally found in the outer regions of big galaxies.

The majority of astronomers, however, persisted with the dark matter idea, and it has become an integral part of the standard model of cosmology, known as Lambda-CDM. Lambda refers to the mysterious 'dark energy' that is speeding up the expansion of the Universe, and CDM to 'cold dark matter'. Because CDM consists of particles moving sluggishly, it is gathered into clumps by gravity – clumps that then pull in ordinary matter to make visible galaxies.

Now, physicists led by Dr Indranil Banik at St Andrews University in Scotland are claiming that observations of the Universe can, in fact, be better explained by a modification of our current theory of gravity than by dark matter.

Lambda-CDM is very good at explaining what we observe, they say. "But this is usually after the event," says Banik. "MOND has been better at predicting things in advance of observations."

One apparent shortcoming of MOND is that it still needs an element of dark matter to explain the motions of galaxies in galaxy clusters – possibly a hypothetical heavy particle known as a sterile neutrino. However, Banik does not see this as necessarily a problem.

"In our Solar System, the anomalous orbits of two planets required new explanations," he says. "For Uranus, it was the pull of a new planet, ●

The MOND hypothesis was the brainchild of Prof Mordechai Milgrom

Neptune – the original dark matter. For Mercury, it was a new theory of gravity, namely Einstein's."

The main thesis of Banik and his St Andrews colleague is that there are several observations that dark matter cannot explain, but that modified gravity can. For instance, the former predicts that satellite galaxies should be distributed spherically, like a swarm of bees – but in many galaxies, including our own, they orbit in a single plane.

Also, the bar-shaped structures made of stars that are seen in the heart of some spiral galaxies should be slowed by a 'dark matter bar' rotating just behind them. "However, in 42 bars whose speeds have been measured, this has not been seen," says Banik.

Proponents of dark matter, on the other hand, see these things as discrepancies that will eventually be explained, not as fatal flaws in the paradigm.

"A lot of interlinked observations make sense only with dark matter," says Prof James Peebles of Princeton University, who won the Nobel Prize for the cold dark matter theory. "That is not to say that the Lambda-CDM theory is the whole truth; but it is a good approximation."

Banik disagrees. However, they do not think experimenters looking for dark matter particles on Earth should give up; merely that they should design future experiments so that, even if they fail to find dark matter candidates, they reveal something important about nature.

"For instance, a search for sterile neutrinos, even if they are not found, will tell us about neutrinos," Banik says. "Since their properties are not predicted by the Standard Model of particle physics, anything we discover would give us hints at the deeper Theory of Everything, of which the Standard Model is thought to be an approximation."

by **MARCUS CHOWN**

Marcus is a former radio astronomer and a science journalist, author and broadcaster. His latest book is Breakthrough *(£9.99, Faber & Faber).*

COMMENT

REWILDING: IS IT ALL JUST A CELEBRITY CULT?

In July, four bison were released in Kent. But is rewilding the best way to boost biodiversity?

Rewilding is all the rage. Landowners are exhorted to rewild farmland, moorland and mountains, while governments are asked to commit to rewilding policies. During No-Mow May (a wonderful initiative) people talked of roadside verges being rewilded. And there's a thriving ecosystem of books, blogs and websites urging homeowners to rewild their gardens, which seems uncannily similar to 'gardening for wildlife'.

In fact, much of what is called rewilding is a rebrand of something we already had. When the Aspinall Foundation announced a plan to move elephants from a zoo in Kent to Kenya, the venture wasn't called 'translocation' or 'captive-release' or 'reintroduction'. No, these elephants were to be 'rewilded'.

Rewilding makes intuitive sense if we take a big picture view of it. The basic idea is that humans have converted land that was once wilderness into some other form of land-use. Rewilding aims to restore land to the way it would be if we weren't around. This wild state, it is presumed, supported a more diverse and functionally complex ecosystem.

We have converted – dewilded, if you like – great swathes of land across the planet for various uses. You live in one such land use (residential). Perhaps you went to the shop (commercial) earlier via a road (transportation) to buy bread (agricultural). Maybe you're reading this on your phone: that requires power (energy generation), materials (mining) and manufacturing (industrial). All of these types of land could be rewilded.

Whatever land you rewild, there are many fundamental questions to ask. When are you rewilding to – pre-Industrial Revolution, pre-agricultural, pre-human? If you rewild your patch to emulate this 'lost' ecosystem, how will it fit within the broader landscape with all its other land-uses? Are you sure your rewilded patch will actually support more biodiversity? How much management are you willing to do to convert the land to this new state, and maintain it? Will you reintroduce species that have been lost?

It is this last question that tends to attract the most headlines. This is especially the case when the reintroduced species are predators, like wolves

WEIZMANN INSTITUTE OF SCIENCE, ALAMY

"We need to make sure rewilding doesn't become a hammer that makes every conservation problem a nail"

ABOVE
Never a native species in the UK, European bison can now be seen in Kent

or lynx, both of whose reintroduction to the UK has been suggested. Recently, another species came into the rewilding spotlight, with headlines proclaiming that "Bison are back in the UK".

European bison nearly went extinct, but thanks to some serious conservation efforts they are recovering well, and a small herd has been released in Kent. 'Rewilding bison' conjures up images of huge herbivores roaming across the landscape, but the reality is somewhat different. A handful of animals will be living behind a fence in a woodland where visitors will be able to go to see them. Another fact that detracts somewhat from the rewilding conceit is the fact that European bison never lived in the UK. They aren't 'back' and haven't been 'rewilded' because they were never here. The species in the UK was the extinct Pleistocene wood bison.

Rewilding is undeniably exciting. It taps into the thought that we are a scourge on the planet and that the best way to change that is to remove us, and let nature take its course. Rewilding projects seem grand and noble, attracting headlines, celebrity endorsement and funding. Surely, then, rewilding is good conservation?

Well, maybe it is sometimes, but there are more than a few problems. First, most conservation *isn't* glamorous, exciting or especially attractive to celebrities, journalists or funders. Rewilding tends to hog the limelight, and that can leave many other ventures, with proven success, woefully overlooked.

A second problem with rewilding is more fundamental. In the developed world, rewilding tends to focus on agricultural or other non-residential land. It is natural for us to view the wider world in the same way. The late biologist Edward Osborne Wilson, for example, suggested putting aside half the world for wildlife. That sounds easy: I can see plenty of land that could be rewilded from the window of my home. But then, I eat food produced through intensive agriculture that I bought at a supermarket. In many parts of the world, people live very differently: they rely on a closer connection to the land, and sometimes that connection goes back for thousands of years. Land that we see as potential rewilded wilderness, they call home.

Rewilding can work, certainly, and is likely to be an important part of our planetary recovery toolkit. But we need to make sure rewilding doesn't become a hammer that makes every conservation problem a nail. If conservation is to work well, we need more than one tool. That means we need to think much harder about how we can share the land we use to live, with the biodiversity we need to survive. **SF**

by **PROF ADAM HART**
(@AdamHartScience)
Adam is a biologist, entomologist and broadcaster who frequently appears on BBC Radio 4 and the BBC World Service.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

INNOVATIONS

FIRST TEST

GOLD STANDARD

Are Sony's new headphones worth their huge price tag? **p46**

FIRST DRIVE

GREEN MILES

Has Toyota's first all-electric car, the BZ4X, been worth the wait? **p48**

NEW TECH

IDEAS WE LIKE

The gadgets we're lusting after this month **p50**

The stripped-back Nothing Phone

VANAMO ONLINE GAME MUSEUM/EVAN AMOS X2

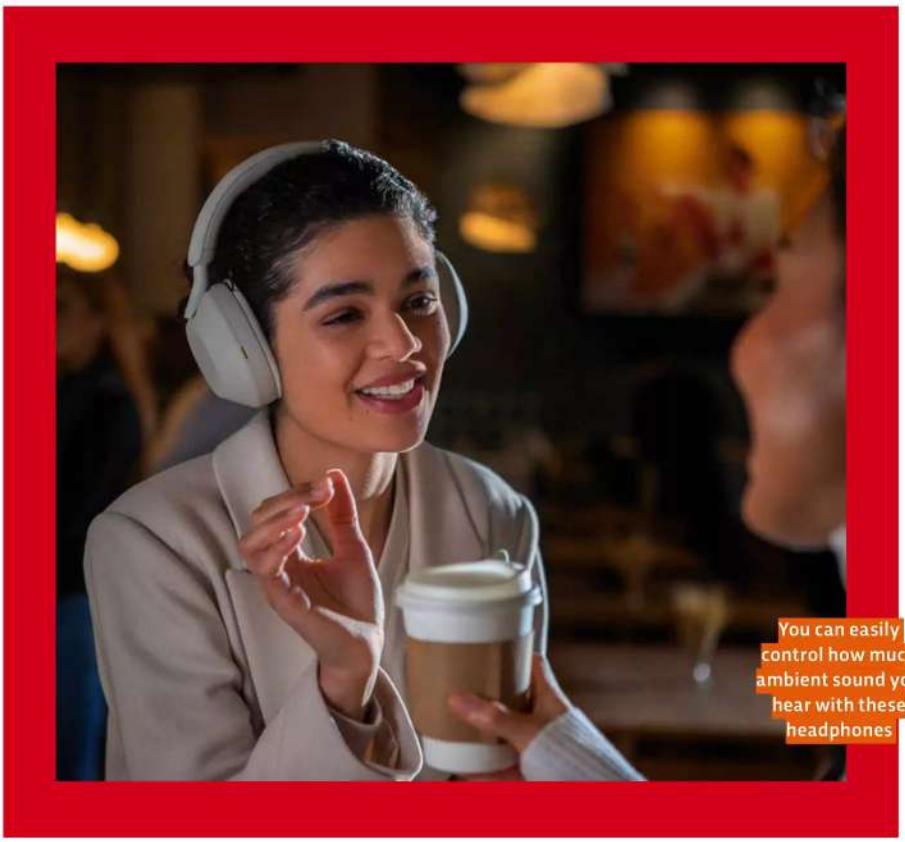
2026 The year that the global headphones market will reach $45.7bn (£37.7bn approx)

$50–$100 The average spend on a pair of headphones (that's £40-£80 approx)

REVIEW

Sony WH-1000XM5: The gold standard for headphones

Some of the best headphones around, says **Alex Hughes**, but they don't come cheap



You can easily control how much ambient sound you hear with these headphones

Let's get this bit out of the way, Sony's new flagship headphones, the WH-1000XM5, cost £379. By any measure that is expensive, even when compared to the likes of Apple and Bang & Olufsen who scoff at the idea of affordable. And with headphone tech improving to the point where you can buy a decent pair for under £100, there's no sane reason to spend nearly £400. Or is there?

If you're not familiar with these headphones, they have a bit of a history. Over the last five years they've scooped up every award in the business, becoming the go-to for anyone looking for noise-cancelling wireless headphones. But with so many competitors now, is this upgrade worth the new, bigger price tag?

A COMPLETE REDESIGN

Since the first iteration of these headphones back in 2016, Sony has relied on a singular design, only making small upgrades here and there. This time, Sony has gone for a complete redesign. The result is a sleek and slim pair of headphones, with minimal lines and uniform materials. It's a design that's reminiscent of the WH-1000XM5's biggest competitor, the Apple AirPods Max.

While the redesign gives the headphones a modern look and feel, the main benefit is the comfort. They are seriously light and can be worn for hours without really noticing them – a feat many over-ears don't manage.

Sony has also added a section of memory foam in the middle of the headband, and the headphones seem to apply just the right amount of clamping so your head doesn't feel like it's being squeezed.

There is one major downside. Unlike previous versions, these cannot be folded up. Instead, the earcups can be rotated to make the headphones flat. They do come with a case to store them, but chucking them in a bag without the case is more of a challenge.

TOP-TIER AUDIO

In terms of audio, the Sony WH-1000XM5 headphones are a leading choice, offering a fantastic performance across genres.

An excellent test is *Bad Guy* by Billie Eilish. The aggressive bass kicks in hard but still with clarity. Equally, tracks like Childish Gambino's *Redbone,* or *Blinding Lights* by The Weeknd, offer a pleasant pump of bass without muddying the mid-range frequencies. Switch to tracks with a rock or metal influence and the headphones still hold up. Led Zeppelin's *Whole Lotta Love* shoots fluently from the left earcup to right, demonstrating their ability around wide soundstages. Push into the grungier *In Bloom* from Nirvana, and the distorted instruments are crisp but still heavy.

While there is a clear proficiency with bass-heavy electronic genres and distortion-led heavier songs, clean tracks like Amy Winehouse's *Rehab* shine, offering a well-balanced performance.

On top of the audio quality itself, one of the best features of these headphones is the noise-cancellation. Thanks to the V1 integrated processor in the headphones and the use of eight exterior microphones, Sony's

noise-cancellation is still market-leading. Whether you're on the London Underground, in a busy part of town, or sat in the office with your co-workers desperately trying to get your attention while you write a headphone review, you won't hear a thing.

FEATURES GALORE

While by no means a deal-breaker, added features and clever tricks are always nice. Luckily, these headphones have plenty.

There are only two buttons on them: one that controls Bluetooth and power, and one for noise cancellation and ambient sound. Everything else is handled via swipes and presses of the earcups. Tap twice to pause, swipe up and down for volume, or back and forth to skip or rewind. Our personal favourite is 'Quick Attention', where covering the right earcup with a cupped hand will turn the volume down and activate ambient sound. This can be used to temporarily hear surrounding noise like a train announcement, have a quick chat, or check to see if someone's knocking the door.

Using this same tech, a setting can be switched on in the Sony app that will adjust the volume based on surrounding noise. This utilises the exterior microphones to detect nearby sounds. If all is quiet, more exterior volume will come in. If things are louder, with lots of traffic or roadworks, for example, the headphones will let less outside sound in.

RATING: ★★★★★

PROS:
- Fantastic audio quality
- Market-leading noise cancellation
- Host of features and adjustments
- Comfortable fit

CONS:
- Don't easily fold down
- Not the cheapest headphones

VERDICT

Like the PlayStation, *The Godfather* films and albums from ABBA, making an improved version of a beloved product is never an easy challenge. And yet, while the WH-1000XM5 headphones only make small improvements over their predecessor, it's in the places that matter.

If you're looking for a new pair of headphones and aren't too worried about how much you're spending, there will be few that offer a better overall package than these.

They sound incredible, whether you're listening to bass-heavy tracks, soft acoustic melodies, or balanced pop anthems, and when combined with the impressive noise-cancelling, comfortable fit and long battery life, these headphones can cut you off from the world for hours on end, with comfort and ease.

3 EXCELLENT, CHEAPER OPTIONS

BOSE SOUNDLINK II
£199.95, bose.co.uk

A slightly older pair of headphones, Bose SoundLink II have stood the test of time, still performing well against the competition despite their age. They sound great, offer a lightweight and comfortable design, and have a build that can stand some wear and tear.

JBL TUNE 750
£102, uk.jbl.com

JBL Tune 750 are a popular pair of over-ear headphones that won't break the bank. Of course, they won't come near to the sound quality or noise-cancellation of Sony WH-1000XM5, but at a fraction of the cost, they still perform surprisingly well in both of these areas.

JABRA ELITE 45H
£89.99, jabra.co.uk

At the sub-£100 mark, the Jabra Elite 45h are easily one of the best options you are going to be able to get. They come with a useful app and an impressive battery life, and while the audio is not going to blow you away, it does achieve a balanced sound that can still impress with bass and some heavier tracks.

First drive: Toyota BZ4X

Has Toyota's first fully electric car been worth the wait, asks **Daniel Bennett**

Toyota isn't afraid to try new things. It made hybrid cars popular with the Prius, it sold the first commercial hydrogen car with the Mirai, and it's now working with the Japanese space agency (JAXA) to put the first proper car on the Moon – one that you won't need to wear a spacesuit to drive. So it feels odd that it's taken so long for the company to launch its first electric car, the BZ4X.

What's was the hold-up? Well, from the outside looking in, it seems Toyota was hoping that motorists would back hydrogen power. It's clear to see why: with a hydrogen fuel cell there's no range anxiety and you refill your tank in largely the same way you do now. Unfortunately, the infrastructure (the refuelling stations) didn't arrive in time to match Toyota's ambitions.

The BZ4X isn't Toyota throwing in the towel on hydrogen; it's bridging the gap until hydrogen becomes a more viable option in the future – we think. So is Toyota's pioneering spirit alive and well in its first battery-power-only car?

The answer is a muddy one. This is a good electric car, it's fun to drive and offers tonnes of space with a smooth ride. Plus, the four-wheel-drive model (4WD) has some pretty smart all-terrain tech to help you when the road runs out. The BZ4X will wade through water, creep down steep verges and skip over rocky surfaces with an easy confidence. The interior has had a modern makeover too, with a clean, sleek finish that's an upgrade over the more utilitarian cabin you'd normally find in a Toyota. All-in-all, this car embodies Toyota's sensible, practical side – what's missing is the company's fun-loving, experimental spirit. The kind of thinking that came up with the i-Road, a lovable three-wheeler electric trike built as way to curb congestion and air pollution.

First off, let's start with the name: BZ4X. The first bit stands for Beyond Zero, the 4 signifies the size (presumably there'll be a BZ3 or 5 in the future) and X means it's an SUV/crossover, just like every other new electric car these days. Functional, but clumsy.

WHAT WE TESTED

TOYOTA BZ4X PREMIERE EDITION

PRICE £51,550
DRIVE: 4WD
RANGE: 286 miles
BATTERY/MOTOR: 71.4kWh battery with front and rear 80KW electric motors
MAX CHARGE RATE: 150kW
0-62MPH: 6.9 seconds
TOP SPEED: 100mph (160km/h)

It's a handsome car, but could do with more of Toyota's playfulness

Fortunately, no one buys a car based on its name, so what's it like on the road? We took the 4WD model (there's also a front-wheel drive (FWD) model) for a few hours around Copenhagen's busy centre, and around a small off-road course to find out. In the driver's seat the steering wheel is compact and sporty. The combo of a lofty driving position and small wheel means that the digital dashboard can be obscured – you sometimes have to peek over or around the wheel to see what's going on. The 215bhp motors are split between either end, making the BZ4X quick off the mark. Meanwhile, the low centre of gravity – thanks to the batteries spread out across the floor of the car – mean that it's agile and taut around corners. It's as fun to drive as an electric SUV can be.

The cabin is spacious and suitably techy, with a big central touchscreen and a console lit up with controls. Everything's sensibly proportioned and ergonomic, as you'd expect from a Toyota. Above all else, the ride is seriously impressive. The BZ4X wafts over potholed city roads and country lanes without fuss, despite the weight of its batteries and thin, low-resistance tyres. The rear seats are big and spacious – you won't have kids kicking you in the back – compared to competitors that tend to struggle to squeeze in batteries and keep the rear cabin roomy. The 412-litre boot is what you'd expect to find on an EV this size, with storage below for the charging cables.

Inside, there's a big central touchscreen to access any apps

The all-important figure, the range, is nothing spectacular. At 317 miles (510km) for the FWD model and 286 miles (460km) on the 4WD model, it's in line with its competition. Though as with all EVs, in the real world you can expect a chunk less than that.

Off-road, the car's X-terrain tech is a fun addition that made light work of the course laid out for us: some ultra-steep ramps were set up so that the car would have only two wheels in contact with the ground at a given moment. We were also invited to drive through a small pool of water to prove it could wade. Both scenarios are unlikely for most UK drivers, but it's nice to see some of Toyota's all-terrain DNA at play.

There is one place where Toyota's trademark playfulness does appear: two small winglets jutting out of the back of the roof that act as a small spoiler or "bunny ears" as the car's assistant chief engineer joyfully shared with me. They're a neat piece of design flair on a handsome but otherwise anonymous-looking car. It's this sense of fun that means Toyota is more than just a company that makes affordable cars, and it's the one thing that its first battery-powered car could have done with more of.

From £41,950 (basic FWD model)
toyota.co.uk

Ideas we like...

Our pick of the month's smartest tech

...running sunglasses get a major upgrade

"The mindset of a god. The image of a warrior" – that is the cringe-inducing, hyperbolic introduction Oakley chose to go with for the Xeus_AG glasses. Sadly, they don't offer omnipotence or barbarian abs, they're just a pair of glasses for runners. They feature trademarked PhysioMorphic geometry, which is a fancy way to say aerodynamic curves, and two-tone chromatic lenses that Oakley claims allows runners to see far more colour and detail. Not for the average runner, these are all about the little wins needed for high-performance, which we'd expect with that price tag.

Oakley Xeus_AG
£384, oakley.com

↑

....advanced augmented reality

There have been plenty of virtual reality headsets, but augmented reality hasn't had quite the same attention. Few companies have made a convincing headset that blends the real world with a digital one, but the Magic Leap 2 is hoping to change all that... for a cool $3,299 (£2,700 approx). The Magic Leap 2 is trying to create realistic augmented reality experiences for education. This could mean interactive planets floating in your living room, or even a digital cadaver in the classroom. Neat.

Magic Leap 2
$3,299 (£2,700 approx), magicleap.com

↑

...a fridge on your back

There are those people who are organised for a barbecue, bringing food and drinks. Then there are those that forget everything. Then there's that one friend who brings a 36-litre, £255 backpack that keeps your drinks cool. It can hold up to 24 cans, plus ice, while also having a separate six-litre reserve for water (or chilled white wine, naturally). Everything stays cold for 70 hours, and there are separate pockets for your phone, wallet, keys and other belongings.

CamelBak Chillibak
£255, camelbak.co.uk

↑

...a keyboard and screen all-in-one

Mostly, mechanical keyboards are all similar, offering a small change to the clicking and clacking of keys, the size of the board or even just how it lights up. Kwumsy clearly decided that it would go slightly further with its K2 keyboard by slapping a 12.6-inch screen on the top. Is this necessary? Not even slightly. Do we want one? Definitely. You can use the screen as an on-the-go monitor, for Spotify controls, to stream YouTube or just to replace your mouse.

Kwumsy K2 keyboard
$399 (£328 approx), kwumsy.com

↑

...a fun take on the mobile phone

Like the first iPhone or folding smartphones, the start-up Nothing has tried to create a revolution with its new handset, the Nothing Phone 1. It offers a familiar phone experience with some cool new additions, such as a built-in ring light to softly illuminate photo subjects. The transparent back on the phone has flashing LEDs to indicate battery life, phone calls, texts and more. The phone's affordable price tag and impressive spec sheet are tempting us.

Nothing Phone 1
£399, nothing.tech

IDEAS WE DON'T LIKE...

...HIGH FASHION TAKES A CONFUSING TURN

'Haute Couture Hi-Fi'. That is how Bang & Olufsen describes its new collaboration with Balenciaga which, we can't help but feel, is another way of saying 'eye-watering price'. The two companies that pride themselves on premium design have joined to make just 20 bags that probably require selling off your worldly belongings to just put down a deposit. It's a solid aluminium, pearl-blasted, polished speaker... that is also a handbag. That means it has three functions: you can blare out your tunes, store an item or two, and inform everyone around you that you have too much money.

Speaker Bag
£TBC, bang-olufsen.com

...A WORLD RECORD WATCH AT A RIDICULOUS PRICE

'Because we can' are three words that when put together always result in something unnecessary. Need proof? Look no further than Ferrari's new watch. The legendary car company has created the world's thinnest mechanical watch. At 1.75mm thick, it is slimmer than an American quarter, but it can't quite take on the British penny for size. Want to buy one for yourself? With only 150 available and an absolutely insane price tag, you'll probably want to think again. Unlike some other pricey watches packed with features, apps and mechanisms, the price you're paying here is fully invested into the thinness.

RM UP-01 Ferrari
$1,888,000, richardmille.com

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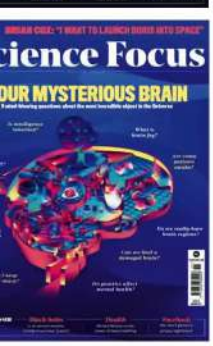


MEET THE ANIMAL ARCHITECTS

WE THINK WE'RE PRETTY CLEVER BY BUILDING THE GHERKIN AND THE SHARD, BUT THESE ENTERPRISING ANIMALS CAN CREATE SOME SMART STRUCTURES OF THEIR OWN... SOME OF WHICH EVEN HAVE BUILT-IN AIR CONDITIONING

WORDS: BEN HOARE

JOAO BURIN/NATUREPL.COM

VAISHAKH MANOHAR/SHUTTERSTOCK

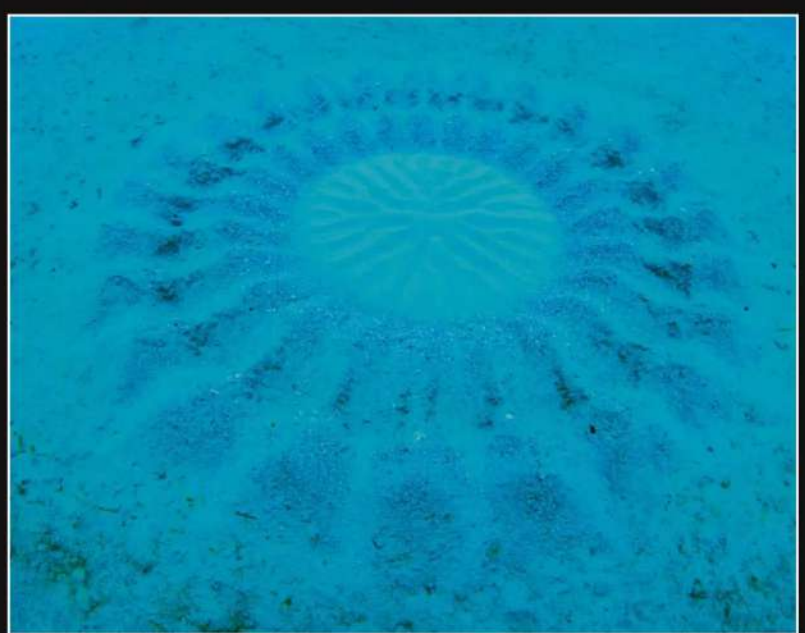
LIVING BRIDGES

Army ants in huge raiding columns will deploy their own bodies to form living bridges so fellow workers can cross gaps quickly. A bridge consists of up to 50 ants and a colony may have 40 or 50 bridges in use at any time. Myrmecologists (people who study ants) at the New Jersey Institute of Technology's Swarm Lab have worked out a simple rule governing this behaviour. Ants only stay in a bridge if they feel sufficient numbers of other ants scurrying over their backs. To justify investing that much labour, the shortcut has to be popular. If fewer ants cross, forming a bridge isn't worth the effort – it's better for the colony if these ants go around the obstacle the long way.

↑

IT'S A WRAP

In 2010, countless trees were left shrouded in swathes of silk in Pakistan following monsoon rains. It's thought that the flood waters forced millions of spiders to take refuge in the trees, where they spun these veil-like webs. Though the identity of the spiders in this image is not known, some species will congregate in composite webs, often resembling huge hammocks or sheets. Spiders live alone as a rule, but some – most of which are small and occur in the tropics – exhibit varying degrees of social behaviour. Communal webs enable them to catch much bigger prey and share the energy-sapping tasks of spinning the webs and maintaining their structure. Occasionally, enormous megawebs appear, covering several hundred square metres in silk, perhaps because a superabundance of prey caused an explosion in the local spider population.



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WHEELS OF FORTUNE

When first discovered in 1995 near the Japanese island of Amami, these submarine 'crop circles' were a mystery. Were they created by animals, currents or something else? Over 15 years later, divers spotted the seabed sculptor: a tiny pufferfish (*Torquigener albomaculosus*) new to science. The male takes around a week to fashion a two-metre-wide nest that dwarfs his 12cm frame. He ploughs through the sediment with his fins and tail whirring to produce symmetrical peaks and troughs. He then sweeps the sandy amphitheatre clean of debris, moving scraps of seaweed or coral to the perimeter. If his labours lure a female, the pair spawn in the middle – but the moment the eggs hatch, he abandons the nest to start all over again. In her book *Eye Of The Shoal*, marine biologist Dr Helen Scales suggests the sculpture may make an ideal soft spot for the developing eggs, with the furrows channelling oxygenated water to the centre.

↑

SNUG AS A BUG

Caddisflies could potentially be the first animal architects. Fossils of the elegant little cases built by their aquatic larvae have been dated to the Early Jurassic (and possibly earlier), well before social insects or birds appeared on Earth. Caddisfly larvae are like weird underwater caterpillars that frequent the bottom of streams and ponds, and many fabricate tubes no thicker than a pencil in which to live. Assembled from grains of sand, fragments of twig or leaf, snail shells and any other debris to hand, the cases protect the soft-bodied larvae from the turbulence of the water current and from predators such as fish. The larvae wriggle out and build new cases as they grow – most will make five in one or two years – before finally leaving the water as short-lived winged adults. French artist Hubert Duprat famously gave larvae gold leaf and pieces of gemstone, with which they created beautiful gilded tubes.

REUTERS, ALAMY, NATURE PRODUCTIONS/NATUREPL.COM

ANN & STEVE TOON/NATUREPL.COM; LUIZ CARLOS FORTI ET AL

POLE POSITION

Weavers are finch-like birds celebrated for their exquisite nests made from knotted strands of dry grass. Most weave spherical or orb-shaped nests, sometimes with a tubular entrance to keep out predators. But sociable weavers, which live in southern Africa, build a giant communal nest that ends up swamping its tree (or telegraph pole, like the one pictured). Some of these sprawling avian high-rises last for up to 100 years and can grow to more than 10 cubic metres in size, making a cosy home for between 200 and 300 breeding pairs of sociable weavers. The spectacular structure protects the residents from extremes of temperature, with every pair housed in a separate flask-like chamber. A 2016 study by researchers at the University of Miami found that 'selfish' birds that lavish time on repairing their own internal living quarters are likely to be on the receiving end of aggression from nest-mates working on the shared exterior thatch. After being apprehended, the selfish birds switched to more community-minded tasks for the good of the colony.

WHAT LIES BENEATH

Without doubt, ants are the greatest farmers after humans. Dependent on the species, they might tend crops (fungi) or herds of livestock (small insects called aphids) in massive subterranean nests. Yet these metropolises and the farming operations that sustain them are largely invisible, leading scientists to find innovative ways of revealing their hidden architecture. One technique is to excavate an abandoned nest and pour concrete into the maze of tunnels and chambers to produce an enormous cast. The labyrinthine nest pictured here was found in Cerrado, which is the largest savannah in South America. It was made by a species of grass-cutting ant that harvests grass, carrying it underground to use as fertiliser for the precious fungi on which the colony feeds. Around 40 tonnes of earth, maybe more, would have been shifted in the nest's construction. In addition to its chambers that act as fungus gardens, the underground city has 'rubbish dumps' where the ants dispose of waste. There is even an air-conditioning system: tunnels dug to maximise the flow of fresh air from the surface.

ALL TOGETHER NOW

We now know that magnetoreception, the ability to detect Earth's magnetic field, is quite common in nature. Everything from sea turtles to songbirds, bats, lobsters, snails, ants, bees and moths have been shown to navigate using it. It's all the more impressive when you consider that our planet's magnetic field is actually extremely weak. There is one species of termite, unique to Australia's Northern Territory, that appears to use this magnetic sense in the construction of its nest mounds. Known as the magnetic termite, its mounds are aligned with the thin edge oriented north-south. One theory is that this ensures the widest edges, and therefore greatest possible surface area, faces east and west to receive the welcome warmth of the morning and evening sunlight, while avoiding the scorching heat of the middle of the day. Seen from the air, the regularly spaced termite mounds form a grid, like some kind of weird cemetery, as you can see in the image above.

by **BEN HOARE**
(@benhoarewild)
Ben is a naturalist and writer. His latest book is Nature's Treasures *(£20, DK Children).*

BIRDY BOUDOIR

In the bird world, males impress would-be partners with extravagant songs, dance moves or nest-building skills, but Australia's great bowerbirds go the extra mile. They spend days constructing elaborate stick-structures whose sole function is to stage their display. The male great bowerbird weaves two thick panels to form a stately thatched avenue one-metre high, then arranges a host of eye-catching objects at either end. His eclectic collection can include everything from leaves to bits of rubbish – plastic (a sign of the times) is especially popular – and individuals have curatorial preferences, with many of this species favouring red or white items such as berries, flowers or shells. Here's the clever bit: objects are displayed in size order, with the smallest ones near the bower, to set up a forced perspective that gives the illusion the bird is larger than he actually is. It's a technique youngsters take years to perfect, and the mental gymnastics involved might explain why the family has bigger brains than other similar-sized birds. **SF**

INGO ARNDT/NATUREPL.COM, GRAEME GUY/NATUREPL.COM

NAPS: A USER'S GUIDE

YOU SNOOZE, YOU WIN. RESEARCH SHOWS THAT NAPPING CAN HAVE A POWERFUL EFFECT ON HEALTH AND COGNITION. THIS IS THE ART OF A SCIENTIFIC SIESTA...

by IAN TAYLOR

"MICRO NAPS CAN ENERGISE YOUR MIND, IMPROVE ALERTNESS AND SUPERCHARGE YOUR CREATIVITY"

Keep this to yourself but I am, quite literally, sleeping on the job. I'm sitting on my desk chair and should be writing this article that you're reading, but my eyes are closed and my forearms are relaxed on the arm rests, palms facing up. There's an apple in my left hand (I'll explain why in a second).

It's a peculiar scene, I'll grant you, but not one of abject laziness, whatever my wife tells you. I'm napping in the name of science, art and productivity. Some of history's greatest thinkers swore by the idea of a power nap, and scientific literature is beginning to suggest they were right to.

In recent years, researchers have found that a short doze can improve everything from memory and creativity to cardiovascular health and immune function. Napping is a superpower, it would seem, capable of restoring body and mind. Some have even described it as a public health intervention waiting to happen – not least because we're all so very tired.

As we know, adults need seven to nine hours of sleep a night. And as we also know, we're not getting it. Screen time, stress, caffeine habits and shift work are all to blame, but according to a YouGov poll earlier this year, one in eight Brits gets less than six hours of shuteye a night and a quarter of us use sleeping pills. Plus, if you believe marketing surveys from mattress companies, we build up more than 30 hours of sleep debt a month.

In turn, the British economy loses £30bn a year because of sleep loss. More importantly, chronic sleep disorders can increase a person's risk of high blood pressure and heart problems, as well as immune system dysfunction and obesity. No wonder sleep has become an obsession, something we track, hack and optimise.

Which brings me back to my desk chair experiment, and that apple I'm holding. Here's the theory, posited by Thomas Edison no less and tested recently by researchers at the Paris Brain Institute: micro naps have the power to energise your mind, improve your alertness and supercharge your creativity – but it's got to be quick, otherwise you slip into the wrong phase of sleep and wake up groggy instead.

It takes a while but I eventually begin to doze off, apple in hand, thoughts and images dancing about my subconscious. Then as the lights go out and I fully lose consciousness, the apple falls from my hand, waking me up with a jolt. It's a weird feeling, but it works, I think. I soon feel more alert than I did before the nap and more lucid; the words come a little more freely.

ILLUSTRATION: JAMES MINCHELL

WHAT HAPPENS TO YOUR BODY DURING A NAP?

Mostly the same things that happen when you sleep at night, just in a single cycle (usually) and over a shorter period of time. First you doze in that hinterland between wakefulness and sleep, which usually lasts around five minutes. Then, as you lose consciousness, you enter stage 2 sleep where your breathing slows, your muscles relax and your core body temperature falls. Brain activity slows down, too.

"Stage 2 sleep is really great for alertness and that pushing-the-reset-button kind of power nap," says Prof Sara Mednick, a sleep researcher at the University of California, Irvine. Some 10 to 25 minutes later, deep sleep (stage 3) begins, characterised by a particular type of brain activity called delta waves. Researchers believe this stage of sleep, which can last up to 40 minutes, is vital recovery time for the body: a biological restoration during which your immune system and other bodily systems get a kind of MOT, and your memories are consolidated.

Lastly there is stage 4 or REM sleep. At this point, you're 60 to 90 minutes into your siesta. This is the point when dreams will be most vivid and your body will enter a sort of paralysis with muscles freezing up. The exception is your eyes, which move quickly beneath the eyelids. "Rapid eye movement (or REM) sleep is good for creativity and perceptual processing and also semantic associations," says Mednick, author of *The Power Of The Downstate*. "You learn new information and encode it and memorise it in slow-wave sleep, but you then integrate that new information into your semantic network during REM."

CAN NAPPING MAKE UP FOR LOST SLEEP?

The reason most of us want to grab a nap is not to hack our creativity so we can write a symphony before 5pm. Mostly, we're just exhausted. Does a nap genuinely let you 'catch up' on sleep lost to late nights, insomnia or teething babies? Absolutely, says neuroscientist Dr Brice Faraut, author of *Saved By The Siesta*.

"The power of the siesta lies precisely in its capacity to produce certain effects of a night-time sleep, but in record time," he says.

Sleep is sleep, is the point. It doesn't really matter if you only grab five hours at night, if you make up for it with another two after lunch. You're still putting the time in. One full sleep cycle lasts around 90 minutes, during which time your body passes through every stage of sleep and all the effects that come with them.

If you wake up from stage 2 sleep, you will likely feel more alert and less fatigued but, says neurologist Prof Guy Leschziner, it's the deeper sleep cycles that are truly restorative on a physiological level. "We think it's the deep sleep, the slow-wave sleep, that is the most important in terms of restoration of function and its impact on blood pressure and various other things," says Leschziner, author of *The Nocturnal Brain*. "So in deep sleep, channels in the brain called the glymphatic system open up and there is an increased removal of metabolites or chemicals from the brain that have been built up during waking hours."

One thing: don't nap for too long or too late in the day because it will likely impact your night-time sleep. It might satisfy your homeostatic drive, which is your body's internal need or pressure for sleep, but "if you take a long nap in the late afternoon, it's highly likely that you'll have a harder time getting sleep at night."

ILLUSTRATIONS: JAMES MINCHELL

CAN NAPPING MAKE YOU MORE CREATIVE?

If you believe the likes of Thomas Edison, Albert Einstein and Salvador Dali, naps absolutely make you more creative. Many famous scientists and artists have relied on naps to sharpen their minds, solve problems or generate ideas. And modern research validates them, with papers showing improvements in a range of cognitive skills from creativity to motor learning after a nap.

Inspired by Edison's method of micronapping described at the beginning of the article, Dr Delphine Oudiette of the Paris Brain Institute devised a study to test it. She presented study participants with a mathematical problem and, if they couldn't solve it, they were asked to recline on a chair and rest. After the break, those people who drifted into stage 1 sleep – that hazy, half-awake state before the shutters come down – were three times more likely to solve the problem than people who didn't nap. "It seems we have a creative switch there when you doze," Oudiette says.

Other areas of cognition seem better served by other phases of sleep. Attention and alertness come from stage 2 sleep.

"And we need slow-wave sleep [stage 3] to improve memory," says Oudiette. "You need at least 40 minutes to get a good amount of slow-wave sleep – but that also increases the chance of sleep inertia and feeling groggy."

She says there's also evidence to suggest that naps can help with emotional response (something that toddlers' parents may verify). "Short sleep may help us digest and regulate our emotions. So if you get an angry email, it might be a good idea to take a nap before you respond."

IS THERE AN EVOLUTIONARY EXPLANATION FOR NAPS?

"All of our rhythms, sleep included, are due to evolution, due to living on a planet that has a Sun and a Moon. And all animals and plants and bacteria have these cycles of rest and activity," says Mednick. Some of the processes that underpin our need for sleep, such as circadian rhythms and homeostatic drive, are thought to have evolutionary roots. "All animals outside of humans are nappers," Mednick adds. "It's almost like, you know, the nappers are the ones that are more naturalistic and the non-nappers somehow have evolved out of napping."

Culture plays a part, too. Siestas are an ingrained part of the Mediterranean lifestyle. In China, it's normal for people to take naps in high school or during the working day. When Mednick studied the napping habits of secondary-age pupils in China, she found that those who don't nap were more likely to have lower academic performance and misconduct. "It's an interesting thought that where napping is a culturally embedded practice, nappers do better."

ILLUSTRATIONS: JAMES MINCHELL

HOW CAN A NAP IMPROVE YOUR HEALTH?

It's hard to overstate the importance of sleep for healthy functioning of your body and mind. "The consequences of non-optimal sleep reverberate over time," says Faraut. "On a short timescale of a few days, it decreases several aspects of cognition, reducing attention, memory formation and the ability to generate ideas. If sleep quality remains poor for an extended period of time, the consequences spread further beyond cognitive functions into the realm of physiology, such as metabolism, neuroendocrine stress, immune and inflammatory systems."

Research has often linked poor sleep to a higher risk of heart disease, obesity and other conditions. It also increases the dangers of co-morbidities like high blood pressure or diabetes, with a number of meta studies showing a link between poor sleep and the risk of an early death.

If naps improve your overall sleep, they have the potential to counteract all of the above. "Studies conducted all over the world show that napping is an adjustable, all-purpose remedy for sleep deficit, a 'medicine' for the future, many of whose virtues are now known to us," says Brice.

"A nap provides all the benefits to be had from the physiological functions of a night's sleep, only on a smaller scale. There is growing scientific evidence that napping not only boosts alertness and cognitive performance, but also reduces the activity of the stress systems and normalises the immune dysfunctions reported as a risk of sleep debt."

So the next time your boss asks why you fell asleep in the mid-afternoon meeting, remember: you're not just resting your eyes; you're giving your entire body a science-backed reset.

WHY DO SOME PEOPLE FEEL WORSE AFTER A NAP?

Some people don't wake up from a nap feeling restored, they feel drugged. They're lethargic, they can't focus and various cognitive abilities are impaired. The feeling is known as 'sleep inertia', describing the zombie-like state between sleep and wakefulness. If you wake from a nap feeling like that, it could be one of two things: bad timing or possibly bad genes.

For most people, waking up from deep sleep (stage 3) is harder. This may be something to do with the delta waves that characterise your brain activity at this stage, or it could be something to do with lower blood flow around your body. One way to counteract this when you're napping is to set an alarm that goes off not during stage 3, but stage 2: around 20 to 30 minutes after you drop off. This means less sleep, but more energy on waking.

It's also possible that you're just not a napper. "We tried to train non-nappers to gain benefits from a nap and found that over a month of nap training there was zero change," says Mednick. "They didn't gain any cognitive benefits and their sleep didn't change. So there could be something fundamentally different between nappers and non-nappers."

Mednick believes that just as people can have what's known as different chronotypes – being a morning person or an evening person – it may be that we're split into nappers and non-nappers. "It seems that there is something biological going on, but we need more research on that."

ILLUSTRATIONS: JAMES MINCHELL

CAN TOO MUCH NAPPING BE A PROBLEM?

Potentially. It's not fully understood, but it seems you can have too much of a good thing. For all the benefits of some strategic shuteye, there are also a number of studies that have shown a link between naps and poor health, especially in older adults.

In 2020, a study presented at the European Society of Cardiology examined data from 20 papers. It found that people who often napped for more than an hour had a 30 per cent higher risk of (all-cause) death and a 34 per cent higher risk of cardiovascular disease compared to non-nappers.

One theory is that longer naps lead to inflammation in the body, which can increase the risk of heart disease over time. However, the same research suggested a protective effect from naps that could last for 30 to 45 minutes.

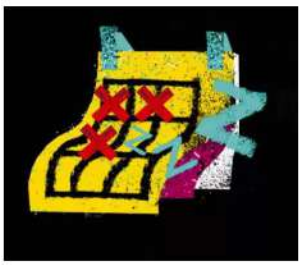
Meanwhile, researchers at the University of California, San Francisco, have linked excessive napping with neurodegeneration in older adults. They found that those who napped for more than an hour a day had a 40 per cent increased risk of developing Alzheimer's disease. But cause and effect isn't clear here, says lead author Dr Yue Leng.

"It's a vicious circle," says Leng. "If you have an increased risk of dementia, you need more naps. And, if you take more naps in this age group, the risk of dementia increases." **SF**

by **IAN TAYLOR** *(@IanStean)*
Ian is a freelance writer and editor.

WHAT'S THE BEST WAY TO TAKE A NAP?

Like any kind of sleep, we'll all have things that work and things that don't when it comes to napping. Here are some soporific tips from our experts



Time it right
"The best times to nap are during the morning, between 9am and noon, to recoup some of the REM sleep lost by interrupting your night sleep too early," says neuroscientist Dr Brice Faraut. "The other time to try is during the early afternoon – for a siesta."

Make it a habit
"Humans are driven by consistencies," says sleep researcher Prof Sara Mednick. "If you want to try establishing naps as part of your routine, try to find a time that you can consistently devote to napping. Make that the time when you just shut off."

Lie back
"The ideal napping position is lying flat on a bed or sofa," says Faraut. "If these aren't available, sleep seated in an armchair and tilt the backrest by at least 40°. Use a neck cushion to support your neck." He also says it's best to banish blue light from screens.

Have a coffee first
It sounds counterintuitive, but if you want a restorative nap and to wake up feeling alert, you can try a coffee, says neuroscientist Dr Delphine Oudiette. "The caffeine will take maybe 40 minutes to kick in, so you can boost the effect of waking up feeling alert."

Make sure you wake up
For a brief power-boost, hold an object in your hand when you nap. "When it falls, you should feel better rested with great ideas," says Oudiette. "Put an alarm on for 20 minutes for a longer nap. And wake up rested, without the sleep inertia effects."

It's time to rethink our relationship with FAT

We've all moaned about a bit of podge on our thighs or tummies, but that fat is not an inert lump of lard – it has an important job to do. And now, scientists are starting to find out even more about its hidden powers

by TOM IRELAND

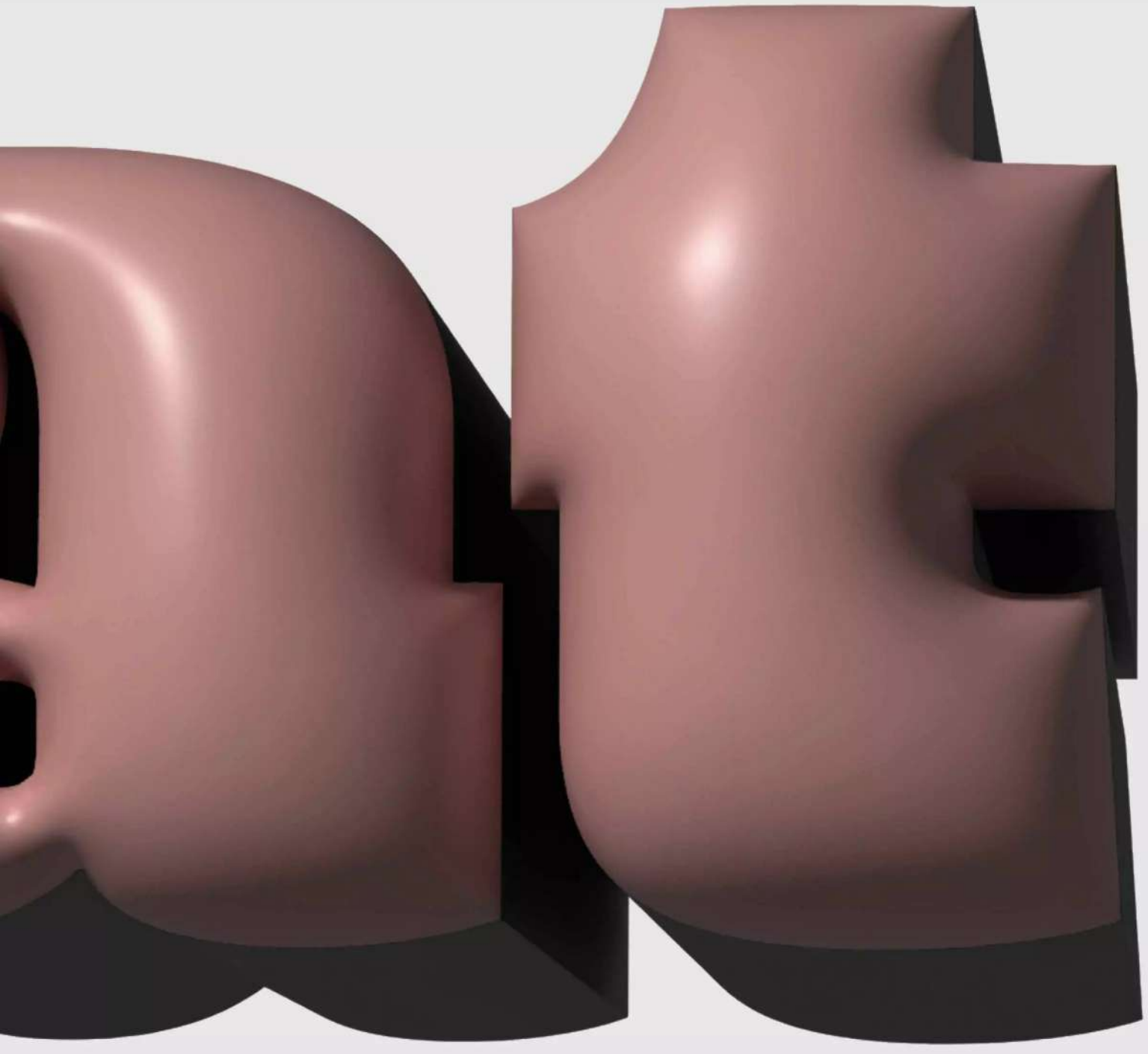


ILLUSTRATION: ANDY POTTS

According to much of what we see on social media, in magazines and on TV, the fat on our bodies is something we need to either fight constantly with exercise and diet, or stop worrying about and celebrate. But in reality, our fat is far more than just a symbol of how healthy our lifestyle is, or of how body confident we may be.

Fat is one of the most important elements of our diet, and the fatty tissue beneath our skin plays a part in keeping us alive and healthy. In chemical terms, fats are long, chain-like molecules that have many roles across all forms of life on Earth. Among their many useful properties, they are an excellent way to store energy, and many organisms convert energy from the food they eat into reserves of fat – from the vegetable oils found in the seeds and fruits of plants, to the inches-thick layer of blubber beneath the skin of large marine mammals.

It is only in recent decades, as an abundance of energy-rich food has caused an epidemic of obesity worldwide, that this vital component of our diet has become so problematic. When

we store too much fat, it causes the vital functions of our fatty tissue to start to fail, leading to many different health issues, from diabetes to stroke to fatty liver disease.

For most of human history, though, our ancestors were more preoccupied with dying from malnutrition and hunger than with looking toned and svelte, and our body fat was the energy store that saved people when food was scarce. In many non-Western cultures, animal fat remains something of a luxury food item, or even a delicacy.

WHAT IS FAT?

When we talk about body fat, we're actually talking about the specialised cells, known as 'adipocytes', which store fat in various places in our bodies. Each cell holds its own droplet of liquid fat and is capable of swelling to accommodate more fat, or shrinking and releasing it as necessary. Together, these fat cells form 'adipose tissue', which is found in deposits just below the skin or deep in the spaces between other organs. As well as storing energy, these fat deposits help to insulate us from the cold and cushion impacts on our joints, the soles of our feet, our palms and our bums – people with no adipose tissue find it hard to sit on a chair for more than a few minutes.

Fatty tissue is part of the complex connective tissue that keeps our organs in place, and is key to building the contours of our faces that make us recognisable. Perhaps more importantly, adipose tissue can be thought of as the body's energy budget-holder, helping ensure different parts of the body have what they need, but always looking to store and save for hard times ahead.

In fact, adipose tissue plays such an important role in tracking our energy requirements and coordinating our metabolism that scientists increasingly think of it as an organ of the body in its own right, albeit one that is distributed throughout the body.

"We need our adipose organ to buffer our normal fluctuations of caloric intake and expenditure," says Prof Stephen O'Rahilly, a co-director of the University of Cambridge's Institute of Metabolic Science. "We don't drip-feed ourselves calories to match exactly the amount we need on a minute-to-minute basis, and after each meal, any calories in excess of what we immediately need are safely stored away in adipocytes.

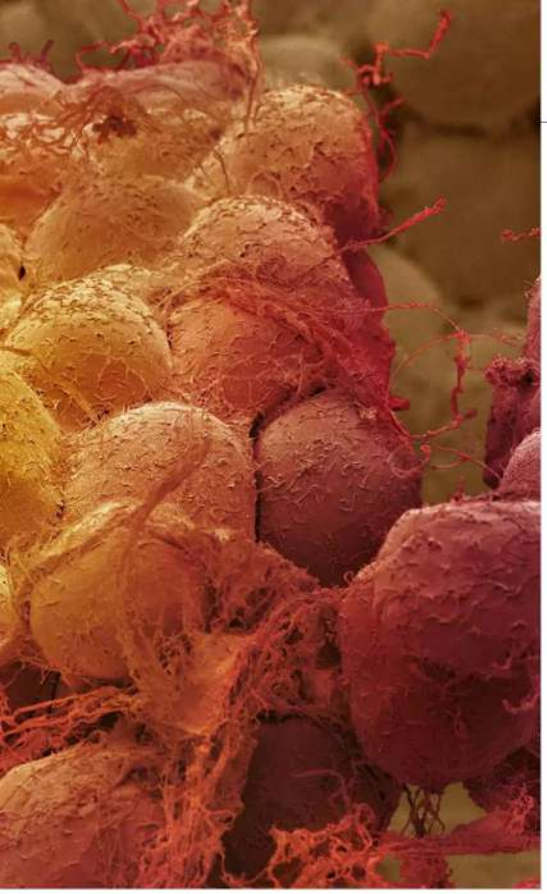
"If, for any reason, we don't have this storage space, then that excess energy in the form of fat is redirected to our bloodstream, liver, muscle or pancreas. None of these are designed to store fat, and all of them are readily damaged by trying to do so."

Far from consisting merely of unsightly lard deposits, the adipose organ has a rich supply of blood vessels and nerves, and produces a variety of hormones and signalling molecules. Not only does the adipose tissue release energy when needed, it also sends information to the brain about the state of our calorie stores, influencing our digestion, appetite and behaviour.

"There is growing evidence that how well – or badly – our adipose organ performs these functions is one of the major determinants of whether, in the face of an excess of calorie ingestion, we develop diabetes, heart attacks, fatty liver disease and so on, or whether we remain overweight but basically healthy," says O'Rahilly.

SCIENCE PHOTO LIBRARY, PROMEDIA/HANS HADORN

"People with no adipose tissue find it hard to sit on a chair for more than a few minutes"



LEFT Fat is stored within your body in specialised cells called adipocytes, seen in this electron micrograph image

BELOW Austrian-born bodybuilder Andreas Münzer, who died aged just 31, allegedly reduced his body fat to zero – but most physiologists would say that is impossible

of past infections, all of which can be drawn on when required. Fatty tissue is also central to the development of the specialist milk-producing glands that feed the babies and young of female mammals after pregnancy.

Interestingly, the number of fat cells in your body does not change in adult life, even when your weight fluctuates. We can grow more fat cells during childhood, and white fat cells may swell with more fat when there is more fat to store – and may even turn brown if a person is subjected to cold for a long period – but it is impossible to rid your body of adipose cells and tissue, no matter how much you diet or exercise. When fatty tissue is physically removed from the body during cosmetic procedures like liposuction, the body compensates for the loss and fat levels soon return to normal, regardless of what patients consume. The lost tissue may even return to the abdomen area or to the spaces between the organs instead of where it was removed from – so while your bum may look great, you suddenly find yourself with a bigger belly than before and poorer overall health.

NOT ALL FATS ARE CREATED EQUAL

There are two main types of fat in our bodies: white and brown. White fat (WAT, or white adipose tissue) is all about storage. Under a microscope, a white fat cell looks like a normal cell with a big glob of fat in the middle. Brown fat (or BAT) is all about heat generation. Brown fat cells look more like normal cells, with smaller droplets of fat dispersed among their components. But they are packed with mitochondria, the bean-shaped energy factories that convert chemicals into the power that drives our metabolism, movement and body heat, giving them a brown appearance. So-called 'beige' fat cells are somewhere between the two.

There are many dietary and genetic factors that can cause people to be prone to weight gain, but one of them may be a genetic disposition to developing more white fat and less brown fat. Studies have shown that people with high levels of brown fat are less likely to develop the cardiovascular and metabolic disorders associated with obesity, such as heart disease and diabetes.

Strangely, white adipose tissue also acts as a kind of reservoir for the special immune cells that help us remember and fight past infections. So you can think of your fat as a kind of wobbly living bank that stores calories, heat and even memories

Some bodybuilders claim to have reduced their body fat to less than 1 per cent of their total weight, but most physiologists believe it is impossible to reduce body fat to such levels: even the most 'shredded' or toned athletes will have 2 to 3 per cent body fat. According to bodybuilding folklore, when Austrian-born muscleman Andreas Münzer died in 1996 his autopsy supposedly revealed he had reduced his body fat percentage to zero. But while he did indeed have a freakishly muscular body, it's unlikely he was anywhere near zero: he actually died from the stress put on his heart and liver by years of over-exercise and steroid abuse.

BODY FAT AND HEALTH

Despite scientists' growing understanding of the importance of fat, high-protein and extremely low-fat diets are still all the rage as people obsess over shedding fat at all costs. But ultra-low fat diets, where fewer than 10 per cent of a person's calories come from fat, are not very healthy in the long term. Some types of fat are essential to help us absorb vitamins and minerals, and when the amount of fat in our diet is far too low, it can make us seriously ill.

The 2007 film *Into The Wild* portrays the last days of Christopher McCandless, a student who died in the Alaskan wilderness after cutting himself off from the outside world and ending up trying to survive on just rabbits and berries. Rabbit meat, although high in protein, has extremely little fat, and McCandless is thought to have developed an acute illness known as 'rabbit malnutrition', where the body uses more energy breaking down the protein in meat than it gets from it. Also known as 'protein poisoning' or 'fat-hunger', the problem affects those living in cold, harsh conditions, where lean animals like birds, rabbits or rodents can be the only food source. Without a source of fat or more energy-rich food, the more the person eats, the more they starve.

Several extremely rare diseases can cause humans to lose more fat than is healthy, or even to be born with no fat at all. With fat having such a central role to play in regulating our energy use and metabolism, these are serious illnesses with a range of long-term health effects. Babies

that are born with no body fat whatsoever look alarmingly muscular and veiny, have trouble staying warm, and quickly develop a suite of serious metabolic conditions such as diabetes.

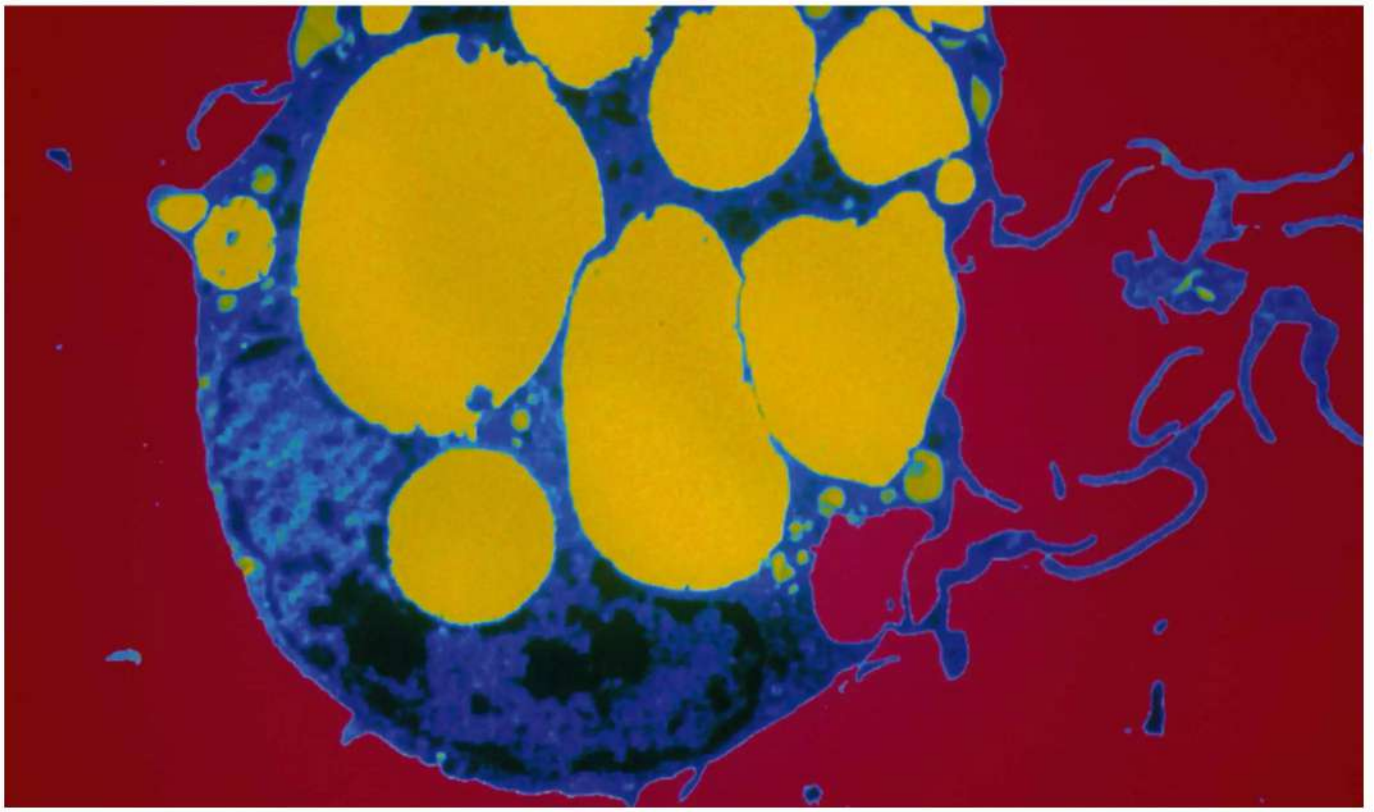
Of course, an excess of fat is not good for us either. An excessive amount of white fat is associated with many health problems, from cardiovascular disease to cancer. Obesity is arguably the defining health issue of our time: our bodies have evolved to store fat whenever we come across it, and many of us now live in a world where fatty food is not just plentiful but hard to avoid. At the same time, we lead lives that involve far less physical activity than the lives of generations before us.

When we ingest more calories than we need, our body still stores the excess energy as fat to protect us in the lean times ahead. When those lean times don't come, our bodies just keep storing more and more fat. On a cellular level, when white fat cells become too large they start to die, attracting the attention of our immune system, and in particular, a type of immune cell known as a macrophage. The macrophages surround the enlarged fat cell and start to release chemicals into the blood that cause inflammation and stress. These chemicals eventually play a role in the body becoming less responsive to insulin, the hormone that regulates blood sugar, which leads to diabetes. Fatty substances like cholesterol enter the bloodstream, creating a build-up of fatty

"Obesity is arguably the defining health issue of our time"

FAR LEFT US adventurer Christopher McCandless died of 'fat hunger' in the Alaskan wilderness in 1992

BELOW A macrophage (white blood cell, seen in black and blue) attacking an over-engorged fat cell (yellow)



THE FAMILY OF CHRISTOPHER MCCANDLESS X2, SCIENCE PHOTO LIBRARY

LEFT Prof Yu-Hua Tseng is looking at ways in which fat can actually be used to help combat obesity

BELOW Atheromatous plaques (build-ups of cholesterol) can harden and narrow the arteries, leading to high blood pressure, and are a leading cause of heart attacks

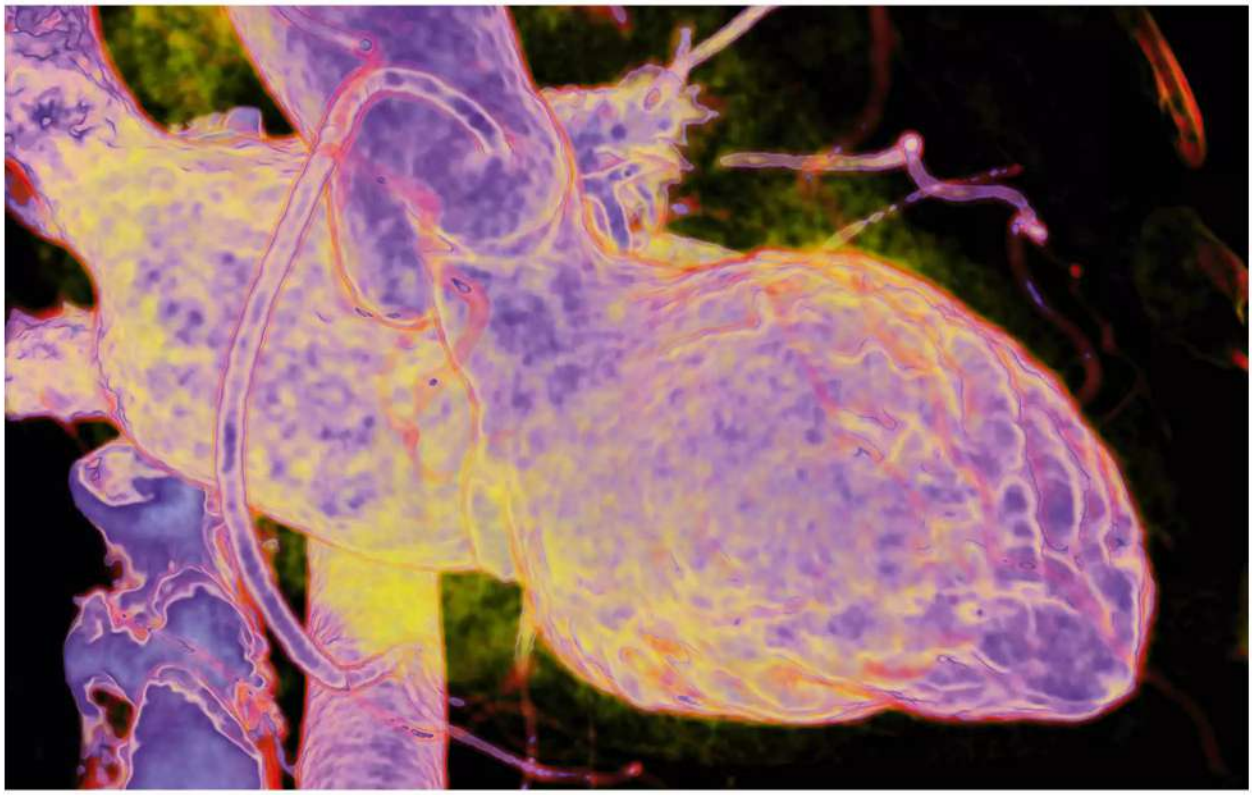
deposits in places like the heart, which can lead to cardiovascular conditions such as high blood pressure, stroke and heart attacks. The chronic inflammation caused by over-enlarged fat cells is also thought to increase the risks of some cancers.

To make matters worse, much of our food is packed with saturated fats, which are more likely to exacerbate these problems than unsaturated fats (see box, right).

TURNING THE TABLES ON FAT

Surprisingly, some scientists are beginning to explore how our own fat can, with a little help, actually help us to lose weight. Prof Yu-Hua Tseng, from Harvard University's Joslin Diabetes Centre, is one of many scientists exploring whether obesity and weight gain can be reversed by activating a person's brown fat, therefore burning away their fat deposits as heat.

"The bodies of obese people have too much white adipose tissue, and often too little brown," she says. "The idea of converting the white tissue into brown is a very attractive approach."



JOHN SOARES, GETTY X3, SHUTTERSTOCK, SCIENCE PHOTO LIBRARY

"Perhaps it's time we built a more sensible relationship with our fat"

There are a number of ways to do this that could become potential obesity treatments, says Tseng. Some scientists are looking at whether white fat cells can be genetically modified to express the proteins that allow brown fat cells to generate heat from fat, essentially 'browning' the white fat so it burns fat rather than storing it. Others are looking at ways to stimulate brown cells to be more active: either by mimicking the body's own molecules that stimulate brown fat to produce heat, or simply by making people cold.

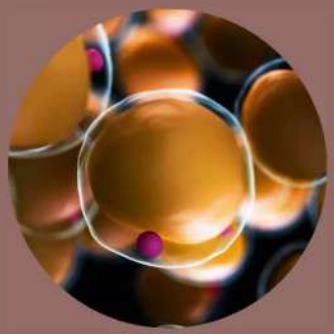
This may sound even worse than going on a diet, but Tseng stresses that it does not take extreme cold to activate your brown fat. "There are studies looking at so-called mild cold exposure," she says. "It's not like freezing cold, it's more like temperatures of around 55°F [12°C]."

Before you turn the air-con right up or run a cold bath, though, Tseng warns that these treatments are still at the proof-of-concept stage, and a long way off being approved for therapeutic use. Eating a balanced diet in moderation and taking plenty of exercise is still the best way to retain a healthy amount of adipose tissue.

Now we know that our fat is such a vital part of our bodies, perhaps it's time we built a more sensible relationship with it – one that is based neither on impossible diets and shame, nor on denial of the deadly reality of obesity. Just like our skin, our teeth or our heart, our body fat should be something we want to take care of and keep healthy. If our fat is healthy, we are healthy. **SF**

by **TOM IRELAND**
(@Tom_J_Ireland)
Tom is the editor of The Biologist *magazine*

BREAKING DOWN THE FAT MYTHS



FAT = HIGH CHOLESTEROL

Not always. Saturated fats, found in meats, cheeses and butter, boost cholesterol in your bloodstream, increasing your chance of stroke and heart disease. So-called trans fats are even worse: these highly processed fats raise cholesterol, make the blood more likely to clot, and cause inflammation. But unsaturated fats from oils, vegetables, fish and nuts actually help reduce cholesterol levels.

CHOLESTEROL = BAD

Some is. There are two types of cholesterol: low-density lipoprotein cholesterol (LDL) is the 'bad' type that hardens the arteries, but high-density lipoprotein cholesterol (HDL) will return excess LDL to the liver for processing. Saturated and trans fats boost LDL and lower HDL, while healthier fats do the opposite. But beware of claims that so-called superfoods can lower your LDL. The best way to do that is simply to avoid eating too much saturated fat.

HIGH BMI = POOR HEALTH

It's complex. Body mass index, or BMI, is a quick but crude way to assess if a person is overweight, based on their height/weight ratio. But it doesn't really tell you how much excess fat you have: people with lots of muscle, or large, dense bones can have high BMIs and be perfectly healthy. Only a full-body X-ray can provide detailed information on fat levels, both under the skin and around the organs.

OLIVE OIL = GOOD HEALTH

True. Many studies have shown that 'Mediterranean' diets, high in olive oil, can benefit people's health and longevity, probably because olive oil contains a high proportion of mono-unsaturated fats, which are very good at lowering LDL cholesterol. But olive oil contains lots of calories – so while it's the healthiest oil to use, don't go too mad on the dressing.

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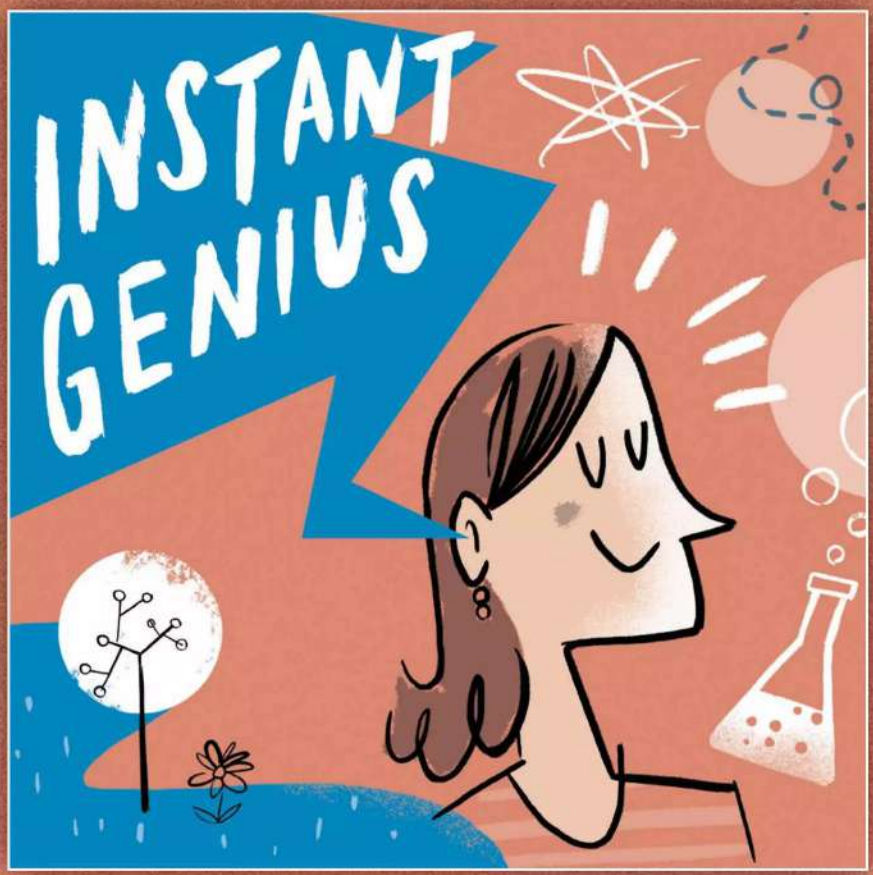

FEATURING

CHILDHOOD
with ***Dr Brenna Hassett***

ANIMAL SENSES
with ***Ed Yong***

COVID NUMBERS
with ***Prof David Spiegelhalter***

SLOTHS
with ***Dr Rebecca Cliffe***

Q&A

YOUR QUESTIONS ANSWERED

... WHY DO DOGS LIKE STICKS SO MUCH?
... HOW WOULD DEEP-SKY OBJECTS APPEAR IF YOU TRAVELLED AT THE SPEED OF LIGHT?
... WHY DOES A CORNEA HEAL AND CARTILAGE WEARS OUT, WHEN NEITHER HAS A BLOOD SUPPLY?
... HOW DO VOLCANIC ERUPTIONS AFFECT CLIMATE CHANGE?
... WHEN'S THE BEST TIME TO VIEW A HARVEST MOON?
... DO HOUSEPLANTS IMPROVE AIR QUALITY?
... DO ANY OTHER ANIMALS SUFFER FROM INSOMNIA?
... WHAT WOULD THE WORLD'S TECHNOLOGICAL ADVANCES LOOK LIKE WITHOUT FOSSIL FUELS?
... HOW DO YOU OVERCOME EXAM ANXIETY?

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ILLUSTRATION: DANIEL BRIGHT

HOW HIGH CAN INSECTS FLY?

Three main factors limit the altitude that winged insects can reach: air density, temperature and oxygen availability. All three relate to the fact that Earth's gravitational pull gets weaker the higher we rise above sea level, allowing air molecules to spread out. The fewer molecules a given volume of air contains, the 'thinner' – or less dense – it becomes.

Flying grows increasingly challenging as air density decreases, because there are fewer molecules for an insect's wings to push against. Insects need oxygen to survive just like we do, but by 6km up, oxygen levels fall below 50 per cent of sea level values, making it harder to maintain wing flapping. Finally, fewer molecules mean less heat generated by molecules bumping into one another. Temperature varies in complex ways with altitude, and some layers of the atmosphere are warmer than others, but between Earth and about 10km up, the temperature steadily drops to less than -50°C.

Despite these hurdles, some insects have developed strategies that allow them to fly at high altitude. In 2014, scientists found that alpine bumblebees living 3.25km above sea level use different flight mechanics at higher elevations, moving their wings in a wider arc to stay aloft in thin air. In the lab, the bees could even fly in chambers that simulated air density and oxygen levels at 9km – higher than Mount Everest! In reality, the temperatures at such altitudes would shut down the flying muscles of bees. ***CP***

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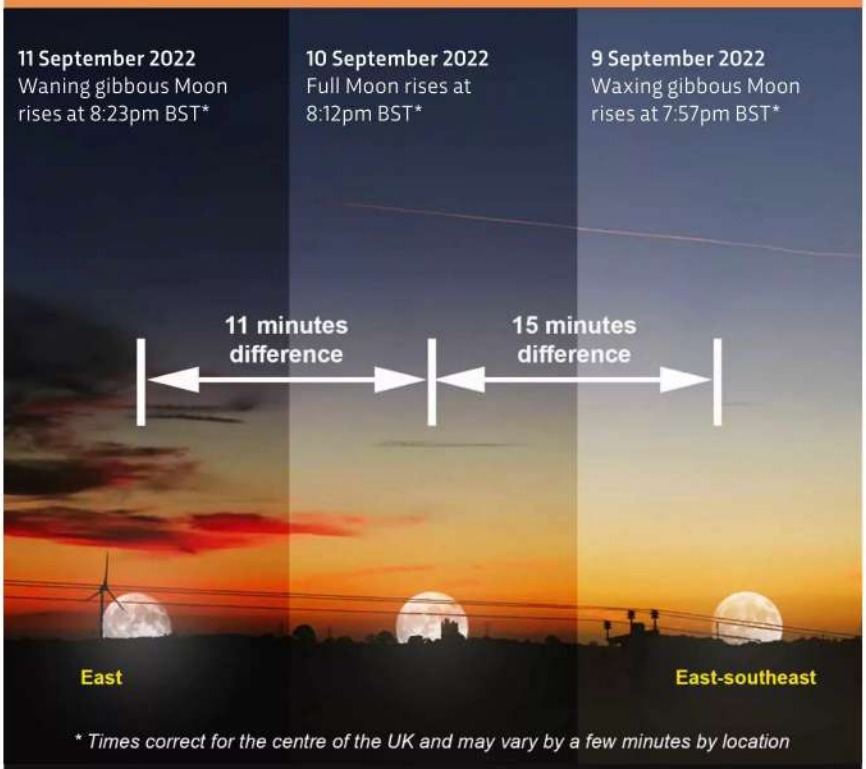
ASTRONOMY FOR BEGINNERS



** Times correct for the centre of the UK and may vary by a few minutes by location*

THE HARVEST MOON

WHEN: EARLY SEPTEMBER

The full Moon on 10 September is the Harvest Moon for 2022, defined as the closest full Moon to the September equinox, which in 2022 occurs on 23 September at 2:04am BST. The tilt and orientation of Earth's axis relative to the Sun makes the Sun appear to rise and fall annually against the background stars. An equinox occurs when the Sun's centre crosses the celestial equator, the projection of Earth's equator into the sky. The September equinox, also known as the northern hemisphere's autumn equinox, is the second of two annual equinoxes.

The nearest full Moons to the September equinox have the property that their fuller phases rise with the minimum difference in time from one night to the next. For example, the 90 per cent-lit waxing gibbous Moon on 7 September rises at 7:15pm BST. On 8 September, now at 96 per cent illumination, the Moon rises at 7:40pm BST, 25 minutes later than it did the previous day. On 9 September, the virtually full Moon rises at 7:57pm BST, 17 minutes later than the day before.

As a result, the fuller phases appear at similar times of the evening, lighting the fields for harvest collection. This is why the nearest full Moon to the September equinox is known as the Harvest Moon. The graphic shows just how close the rise times are either side of the full Moon on 10 September.

The earliest Harvest Moon occurs on 8 September, and the latest on 7 October. In reality, the full Moons that occur a month each side of the Harvest Moon exhibit only marginally greater rise time differences. The average fuller phase moonrise difference is around 50 minutes, the greatest occurring near the March equinox when it's around 80 to 90 minutes. ***PL***

CHRIS STRACEY, POOLE

IF I TRAVELLED AT LIGHT SPEED, WOULD FAR AWAY OBJECTS DISAPPEAR?

On Earth we can still see deep-space objects which no longer exist because their light takes a finite time to reach us. If we begin travelling towards such an object, we will continue to see its light, but will see its demise earlier than if we had stayed stationary, simply because we are decreasing the distance the light has to travel. Similarly, if we begin moving away from the object, we will be able to see it for longer than if we remained stationary, because we are increasing that distance. So, some objects will indeed disappear from our sight because we are moving – this is true whatever speed we travel, but the effect obviously increases the faster you go.

However, there are other factors at play when travelling close to the speed of light. First, the Doppler Effect means objects behind us will become redder, while those ahead will become bluer. At a great enough speed, objects will disappear from sight because their light is shifted out of the visible part of the spectrum. Also, as your speed increases, your field of view becomes narrower and brighter in the direction of motion and objects appear smaller and further away. Eventually, even objects which are behind you rotate into view in front of you. At light speed you would see only an infinitely small, infinitely bright spot ahead of you, and darkness everywhere else! So, if you are travelling close to light speed, you will not be able to distinguish individual objects and notice whether they have disappeared or not! ***AGu***

How would the Crab Nebula appear if it was approached at light speed?

GETTY IMAGES X2, ALAMY, NASA/ESA/CSA/JAMES WEBB SPACE TELESCOPE ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

MARK R SLACK, VIA EMAIL

WHY DOES A CORNEA HEAL AND CARTILAGE WEARS OUT, WHEN NEITHER HAS A BLOOD SUPPLY?

The outer layer of the cornea is called the epithelium. It is made up of cells that are constantly turned over, as the outermost cells are shed into the tear film. Corneal abrasions usually affect this layer. The entire epithelium is turned over in approximately 7-10 days, and this process is accelerated during wound healing.

Historically, cartilage was thought to 'wear and tear' as we age, leading to osteoarthritis. But we now know that it's a disease of the entire joint, including bone, cartilage, ligaments, fat and the tissues lining the joint. Beyond simple wear and tear, osteoarthritis can cause cartilage to degrade, change bone shape and cause inflammation – all of which are difficult to reverse. ***NM***

SARAH HARTLEY, DEVON

WHY DO DOGS LIKE STICKS SO MUCH?

What's brown and sticky? Hurray for sticks; nature's very own dog toy. Not only are they free, they're also readily available, biodegradable and fun for our four-legged friends who like to fetch, gnaw and parade around with them. For some pooches, the stick's allure may come from its texture, which feels good to chomp on, but this is not recommended as splinters can harm. For others, it's a breed thing. Cocker spaniels and Labradors, for example, have been selectively bred to retrieve and carry things. For many though, it's just fun. Once they learn that 'stick = splendid playtime with my human', many dogs will go out of their way to source a good stick. Be aware that throwing sticks for your pup can lead to injuries, so vets recommend safer alternatives such as rubber sticks or a dog frisbee. ***HP***

NATURE'S WEIRDEST ANIMALS...

THE COELACANTH

For years, scientists thought it died out with the dinosaurs. The only known coelacanths were fossils. Then in 1938, a South African museum curator found a dead one in a fisherman's catch. Live specimens were later caught, proving that this curious fish was never actually exinct.

Living deep in the waters around Africa's Comoro Islands and Indonesia's Sulawesi, this big, bottom-dweller is unlike any other living fish. Weird True Fact 1: it has eight fins, including two pairs which stick out from the body like legs. It doesn't use them for walking though. They're more like the stabilisers you get on kids' bikes. WTF 2: instead of a bony backbone, coelacanths have a hollow, oil-filled tube called a notochord. WTF 3: they are fatheads. The brain occupies just 1.5 per cent of its braincase and the rest is filled with fat. It also has thick scales, a unique jaw joint, a huge gape, and an organ in the snout for electroreception. By detecting electrostatic fields, they can use this intel to avoid obstacles and detect prey. ***HP***

DAVID SCOTT, PORT ST MARY, ISLE OF MAN

HOW DO VOLCANIC ERUPTIONS AFFECT CLIMATE CHANGE?

Explosive eruptions can cause substantial cooling of global surface temperatures, lasting for anywhere between 1 to 10 years. We have known about this cooling for centuries, with our temperature records often showing distinct dips following major eruptions. One of the clearest examples being the 1815 eruption of Mount Tambora, an explosive event that caused a 1°C drop in global land temperatures. The eruption was so energetic that volcanic gases were injected into the stratosphere, the layer of the atmosphere 10 to 50km above the surface. This caused incoming sunlight to be blocked, meaning that not as much reached the Earth's surface.

While more explosive volcanoes tend to cause more global cooling, it's not always the case. It depends on the ejected gases reaching the stratosphere, and on wind systems. Mount St Helens, one of the most violent eruptions of modern time, hardly made a dent in global temperatures due to its gases not persisting in the stratosphere.

Could volcanic eruptions mitigate the increased temperatures from climate change? Unfortunately not. Volcanic eruptions have occurred over history and are a natural component of our atmosphere. Their effect is also short-lived, with surface cooling from eruptions lasting a matter of years, while surface warming from excessive carbon dioxide emissions lasts for thousands. ***DM***

DERRYCK MORTON, POUGHILL, DEVON

IF THE MOON WERE BIGGER, AT WHAT POINT WOULD IT BE DEEMED A PLANET AND THE EARTH AND 'MOON' A 'BINARY PLANET' SYSTEM?

The criteria which distinguish between a 'binary planet' (or 'double planet') and a 'planet-moon system' (or 'planet-satellite system') are, unfortunately, not well defined. An obvious criterion is the ratio of the two objects' masses. A value close to 1 implies the objects are very similar in mass, but how close to 1 does the ratio have to be for the system to be a double planet rather than a planet and moon? The Earth-Moon system has a ratio of only 0.01230, while the Pluto-Charon system has a ratio of 0.122. Neither is particularly close to 1 and so neither is regarded as a binary planet.

Other criteria have been suggested, such as the position of the 'barycentre' about which the two objects orbit, the strength of the gravitational force of the parent star on the pair, or how the objects were formed in the first place. The Pluto-Charon system could be described as a double planet because both objects orbit around a point above their surfaces. This is not true of the Earth-Moon system, as the barycentre is about 1,700km below Earth's surface. But this, and other definitions, are not wholly adequate – and none are fully adopted by astronomers. ***AGu***

GETTY IMAGES X3 ILLUSTRATION: DANIEL BRIGHT

SAM NICHOLLS, VIA EMAIL

DO HOUSEPLANTS ACTUALLY IMPROVE AIR QUALITY?

Most of us have been spending a lot more time at home these past couple of years – prompting us to ask questions about the quality of the indoor air we breathe. Pre-COVID reports show that Brits spend more than 90 per cent of our time indoors, where levels of some toxins can be up to five times greater than they are outdoors. The internet is full of claims that houseplants can help, with just about every wellbeing site boasting its own top-10 rundown of the most powerful air-purifying plants. But is there any truth to the claims?

Unfortunately, not much. Most of the articles, if they cite any evidence, point to a NASA study from 1989. Back then, scientists were investigating plants' ability to remove harmful chemicals called volatile organic compounds (VOCs) from the air of sealed environments such as space stations. In our homes and offices, sources of VOCs include paints, varnishes, furniture, carpets and printers. The study found that over a 24-hour period, several species of plant could indeed remove up to 70 per cent of one or more of the three VOCs tested.

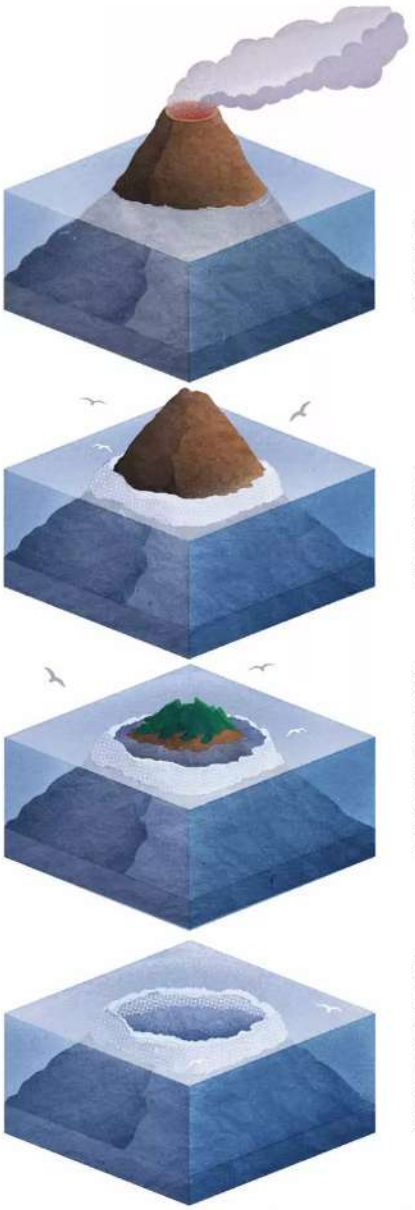
But the results don't translate well to the typical home or office, according to a 2019 review that revisited the NASA data, along with 11 other studies from the decades since. For starters, the experiments typically used fans to waft the VOCs over the plants, and carbon filters to collect them – setups that most of us don't have in our homes. More importantly, the plants were placed in small, sealed chambers. But the buildings we live and work in are surprisingly leaky. In fact, the researchers estimate that you'd need to squeeze between 10 and 1,000 plants into each square metre of your home to approach the rates of VOC removal already happening through passive indoor-outdoor air exchange.

Research shows that houseplants do have a range of other benefits, however. They help regulate humidity. They can improve mood and boost productivity. And they look good, to boot. But if you want to freshen up the air in your home, your best bet is to buy an air purifier with a high-quality filter or – depending on where you live – to open a window. ***CP***

SUZIE SCOTT, EDINBURGH

HOW ARE ATOLLS FORMED?

Atolls are ring-shaped coral reef islands in the open ocean with a central lagoon. They're found in warm, tropical or subtropical waters where corals can flourish. Of the 439 atolls in the world, most are located in the Pacific Ocean. Atolls have vibrant ecosystems, and the parts of the reef that lay above the water may even become forested. Both the atoll and the ecosystem can take millions of years to evolve.



Step 1
An underwater volcano builds up from the seafloor and breaks above the surface of the water.

Step 2
As the volcano goes extinct, or becomes temporarily dormant, algae and coral start to colonise the shore, forming a fringing reef.

Step 3
Erosion or a subsiding oceanic plate causes the volcanic island to sink into the ocean. As it does so, a lagoon starts to form between the reef and the volcano. Meanwhile, the coral and algae keep pace, continuously building up the reef as it becomes a barrier reef.

Step 4
When the volcanic island disappears, having become completely submerged below the water, it leaves behind a lagoon protected by the barrier reef; an atoll of coral limestone composed of calcium carbonate.

However, some scientists studying atolls in the Maldives have proposed an alternate theory, whereby cyclical changes in sea level are responsible. As falling sea levels expose a bank of organic carbonate rock, mildly acidic rain erodes it, leaving behind a depression where water can pool. As sea levels rise, corals keep pace and build up around this lagoon, forming an atoll without the need for a volcano.

DEAR DOCTOR...

MENTAL HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

HOW DO I STOP TURNING INTO A BUNDLE OF NERVES WHEN I'M TAKING EXAMS?

Few people like formal tests, but for people with 'test anxiety' the fear and stress become especially problematic – they dread exams in advance, experience unpleasant symptoms during the test and fret intensively afterwards. Psychologists say there are two main components to test anxiety – a cognitive element that involves worrying about the consequences of poor performance (for example, 'I'll never get a place at a good university') and an emotional element related to the physical effects of stress during the test, such as a racing heart and sweaty palms. In worst case scenarios, people with test anxiety will avoid evaluations and procrastinate over their studies, ultimately harming their education and career prospects.

The good news is that there is a significant amount of research on ways to deal with test anxiety. Many of these interventions are unsurprising and involve using cognitive behavioural therapy techniques to deal with anxious thoughts and feelings, combined with building test-taking and study skills. More creative approaches include colouring mandalas (geometric shapes) or doing physical exercises to calm your nerves. Other anxiety-busting approaches with some support include taking time at the start of a test to skim through the questions, and spending 10 minutes before an exam writing about your values and what matters to you – a stress-busting strategy known as 'self-affirmation'. For more resources, visit this site from Ofqual **bit.ly/test-anxiety-1** ***CJ***

JENNY EDWARDS, VIA EMAIL

DO ANY OTHER ANIMALS GET INSOMNIA?

Other animals display insomnia-like behaviour. For example, in a seminal study it was found that when male rats were rehomed from their individual cages into those of other male rats, they displayed what resembled stress-induced insomnia. Furthermore, 'insomnia-like flies' take longer than others to fall asleep and maintain sleep to a lesser extent.

Despite this, the authors of an excellent review of animal models of sleep disorders noted that insomnia involves an inability to sleep – however, it is not clear whether these animals are attempting and failing to sleep. Additionally, insomnia involves a subjective component (best assessed by asking someone about their sleep) which creates obvious challenges when it is considered in non-human animals. ***AGr***

PAUL FROM NC, VIA EMAIL

WHY DO BULLETS MAKE A ZING SOUND IN MOVIES?

Bullets from real guns only 'zing' if they ricochet off something hard at a fairly shallow angle. This causes them to tumble very rapidly and the turbulence of this motion as they fly off sounds like a high pitched whine that fades into the distance. TV shows and movies overused this sound effect so much in the past that we have now come to expect it. ***LV***

QUESTION OF THE MONTH

ANDY NEWELL, KNARESBOROUGH, YORKSHIRE

IF THE ANCIENT CARBONIFEROUS FORESTS DIDN'T GO ON TO CREATE THE OIL AND GAS FIELDS WE EXPLOIT FOR FOSSIL FUELS, HOW DIFFERENT WOULD OUR WORLD LOOK TODAY IN TERMS OF TECHNOLOGY AND THE ENVIRONMENT?

The Industrial Revolution was largely powered by coal. Wood and charcoal were used as fuel, and to smelt iron, before then, but wood was already becoming scarce in Britain in the 16th Century when the population was still under 10 million. Trees are slow to replace and take up a lot of land area. Wood also has only half the energy density of coal, so you need to burn more of it. Political power probably would have shifted towards Russia, Canada and South America with their huge areas of forested land.

Without coal and oil, early chemists would have faced the much more challenging proposition of synthesising long-chain hydrocarbons from ethanol or vegetable oil. Plastics and synthetic rubber would not be developed until much later and would probably have been too expensive to use for toys and disposable packaging. Worse, natural gas is an essential ingredient for production of ammonia fertilisers. Without them, the world would need four times as much agricultural land to produce the same amount of food, which would sharply limit population growth.

Electrical power would still be perfectly possible; wind turbines and hydroelectric dams were already in use in the 19th Century and could have been developed to fulfil all our needs. But electronics without plastic for insulation would be very challenging. Computers, if they existed, would be large and primitive. Atmospheric CO_2 would still be at pre-industrial levels, but smog and soot would be an even bigger problem as vast amounts of wood were burned for heat, cooking and industry. This could even lead to climate cooling, by blocking the sunlight reaching the surface. Limited land area might result in more wars for territorial control, but they would be fought with muskets and cannons since petrochemicals are also a vital ingredient of high explosives. ***LV***

ALAMY, GETTY IMAGES. ILLUSTRATION: DANIEL BRIGHT

WINNER

The winner of next issue's *Question Of The Month* wins a **Geomag Mechanics Challenge Strike! kit** worth £53.49. For one to four players, the game combines the forces of magnetism with a world of mechanical construction. The player with the best grasp of magnets and gravity will win the game!

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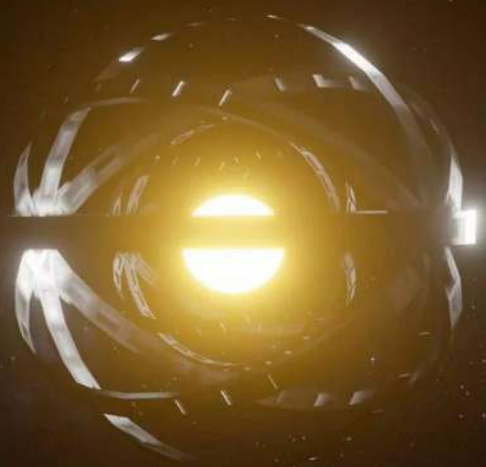
THE EXPLAINER

DYSON SPHERES

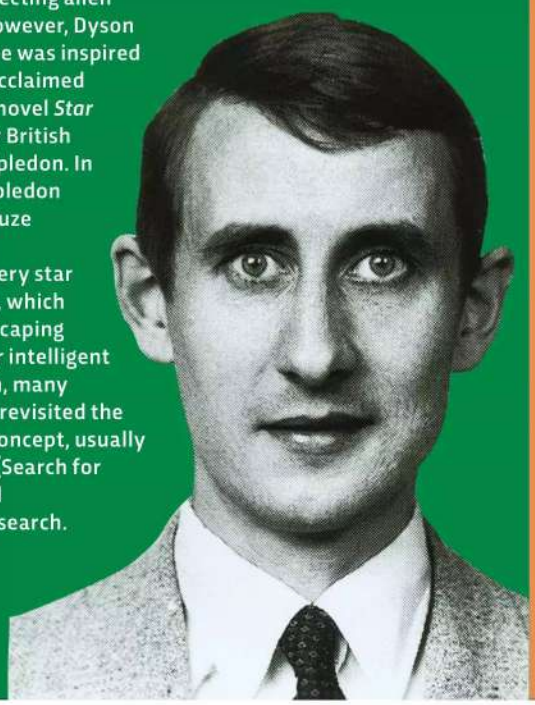
WHAT IS A DYSON SPHERE?

A Dyson sphere is a hypothetical, large mechanical structure – a megastructure – designed to harness the energy of stellar nuclear furnaces. The basic idea is that a structure is constructed around a star which converts, stores or otherwise utilises, the star's radiant energy. These facilities are postulated as the most likely, necessary and economical way of addressing the colossal energy needs of both future human civilisation and, possibly, advanced alien civilisations elsewhere in the cosmos.



WHO THEORISED THEM? AND WHEN?

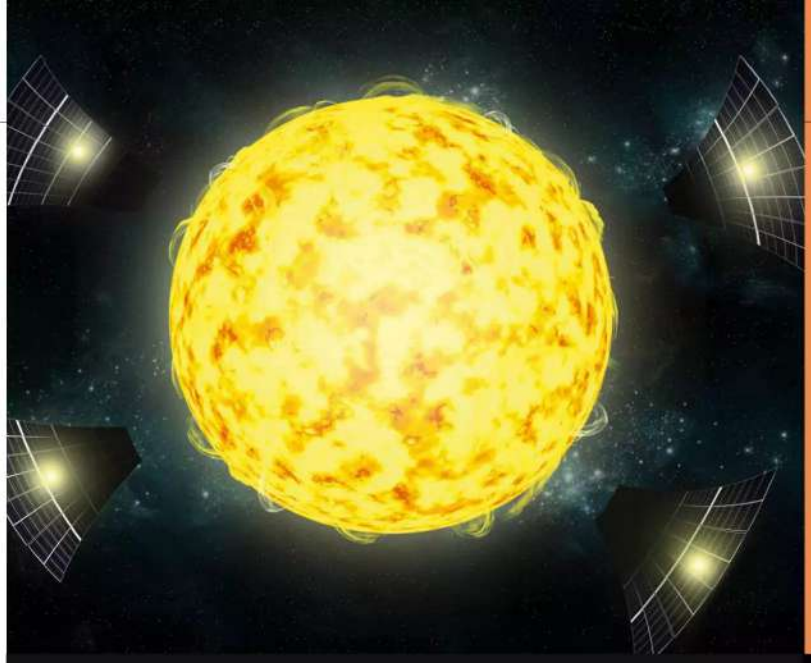
The Dyson sphere concept is named after physicist Freeman Dyson (1923-2020) who, in 1960, discussed the idea in a short scientific paper concerning methods of detecting alien civilisations. However, Dyson admitted that he was inspired by the highly-acclaimed science fiction novel *Star Maker* (1937) by British author Olaf Stapledon. In *Star Maker*, Stapledon described "a gauze of light traps" surrounding every star in the Universe, which "focused the escaping solar energy for intelligent use". Since then, many scientists have revisited the Dyson sphere concept, usually as part of SETI (Search for Extraterrestrial Intelligence) research.



COULD THEY REALLY EXIST?

There is, as yet, no evidence that Dyson spheres, or anything similar, exist anywhere in the Universe. However, scientists can say something about whether they are 'allowable'. Firstly, although such technology is way beyond what is currently possible for Earth-bound intelligence, there are no known insurmountable barriers to their construction. Given enough incentive, resources and technological advancement, Dyson spheres are certainly possible. One researcher estimates that humans could attempt such a feat within the next 100 years or so. Other researchers claim this is wildly optimistic.

Astronomers have actually placed some limits on how many Dyson spheres may be lurking out there in the cosmos. To do this, some assumptions are made about how these structures would affect the emergent starlight of the stars they surround. For example, most designs would block some of their host star's light, leading to a drop in their optical brightness. They may also result in waste heat that would be emitted as infrared radiation. By looking carefully for such deficits or excesses in the light of thousands of stars, one estimate suggests up to 10,000 stars could host Dyson spheres within a radius of about 16,000 light-years of Earth (by comparison the distance to the Milky Way's centre is about 26,000 light-years). Of course, that doesn't mean that Dyson spheres do exist, only that they could.

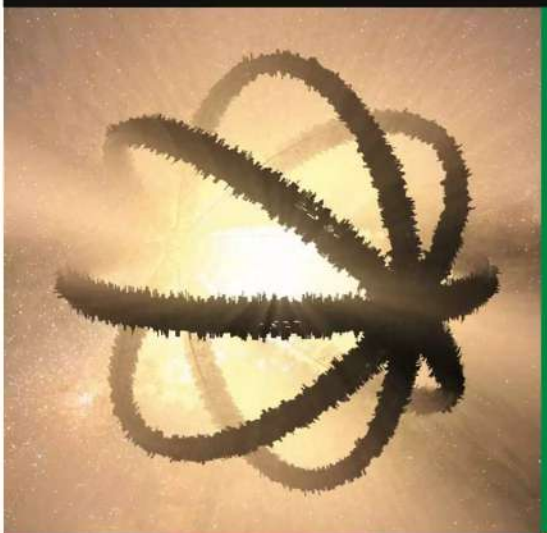


HOW DO DYSON SPHERES WORK?

The purpose of a Dyson sphere is to harness the colossal energy released by the host star. We already have the basic technology to do this – in the form of 'solar cells'. These use a process called the 'photovoltaic effect', whereby photons knock electrons out of atoms, thus creating a separation of charge within a material, resulting in an electric current. Dyson spheres, whatever their form, are likely to use this process for the generation of energy. Some researchers envisage this energy being transferred by some form of wireless technology to the nearby civilisation, probably on a habitable planet in orbit around the host star.

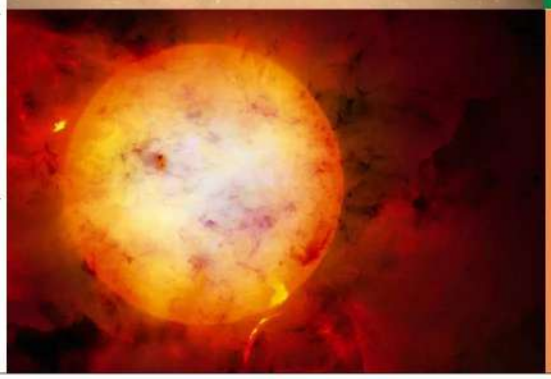
HOW HAVE DYSON SPHERES BEEN DEPICTED IN SCIENCE FICTION?

Science fiction writers have often envisaged a Dyson sphere as a rigid structure completely enclosing a star, which is not the original idea put forward by Dyson, and which is actually considered the least likely solution. But ring-like structures and satellite swarms have also appeared in fictional universes. Some notable novels involving Dyson spheres, or similar concepts, include Fritz Leiber's *The Wanderer* (1964), Larry Niven's *Ringworld* (1970) and Stephen Baxter's *The Time Ships* (1995). On TV, *Star Trek: The Next Generation* featured a Dyson sphere in the episode titled 'Relics' (1992).



HOW DO YOU BUILD A DYSON SPHERE?

One possibility, as the name implies, involves construction of a spherical framework around a star (usually called a 'Dyson shell'). To control the effects of the star's gravity and radiation pressure, such a structure would probably need to be both flexible and have a propulsion system to alter its position. Some researchers suggest, however, that maintaining stability in such spherical structures may not be possible. Dyson spheres would probably not be spheres at all. Some concepts envisage ring structures, dense swarms of orbiting satellites, or swarms of 'statites' (static satellites) that remain motionless with respect to the star (called a Dyson 'bubble'). Engineers have proposed that these structures could be built remotely by armies of space-borne robots and that the materials for construction can be obtained by dismantling terrestrial planets. Other more exotic forms of Dyson structures have also been postulated, such as galaxy-sized clouds of 'smart dust' that harness the energy of billions of stars.



COULD THEY BE RESPONSIBLE FOR 'STRANGE' SIGNALS FROM SPACE?

There are many 'strange' or unexplained signals coming from space, but currently none of them are candidates for Dyson spheres. A few years ago, a star colloquially known as 'Tabby's Star' showed random dips in brightness that were suggestive of a Dyson sphere, but further observations revealed that dust clouds orbiting the star were actually the culprit.

by **DR ALASTAIR GUNN**
Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.

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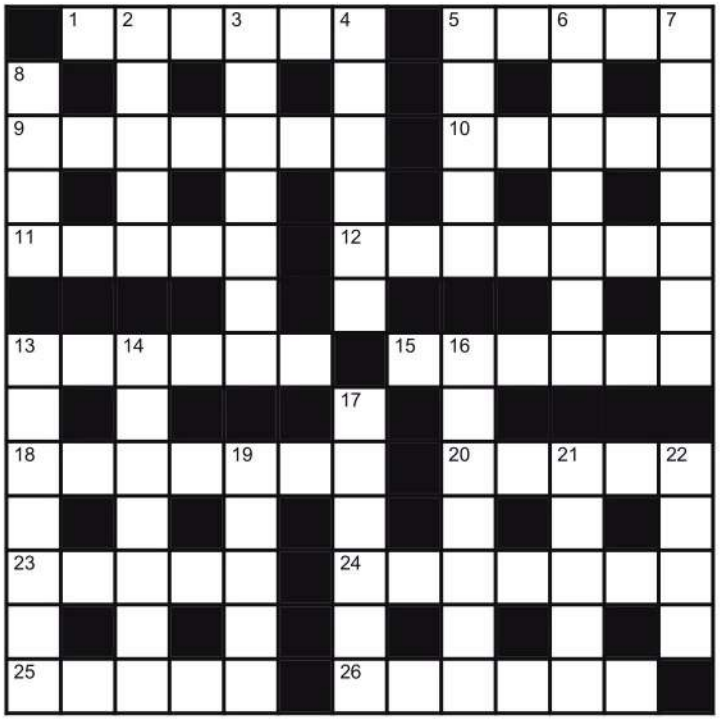
CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Fellow joins the Spanish church (6)
5 Fund energy, down, out of sorts (5)
9 Any curve inside brings disorder (7)
10 Object after fun turned inappropriate (5)
11 Extremist often seen with Violet? (5)
12 Toured around, taking note to become noticeable (7)
13 Couple by river, having a drink (6)
15 Caught you and me hiding deed that's prickly (6)
18 Mark's attorney gets sick after church (7)
20 Bartok's first version of duet sent round for first performance (5)
23 Victor misses front part of target (5)
24 Willing student joins a new orchestra (7)
25 Concurred, taking front off vice (5)
26 Two fivers returned for a cheese ingredient (6)

DOWN

2 The artist has concern for others (5)
3 Wolves on time for collection (7)
4 Wally somehow has nothing to hide (3,3)
5 Pure fluid gets temperature to break out (5)
6 Non-payment is the preselected option (7)
7 Stupid, not hiring a comedian (7)
8 Returned without cent, start to use capital (4)
13 Support music accompanying a singer (7)
14 Teen lad somehow became firm (2,5)
16 Terribly bad sign in the middle (7)
17 Harass an animal (6)
19 Left university, free to be sensational (5)
21 Swelling starts to build under Len's glass eye (5)
22 What's essential to most unexcited series of notes (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

FUTURE SPACECRAFT

HEART AEROSPACE

PLUS

THE VAGUS NERVE

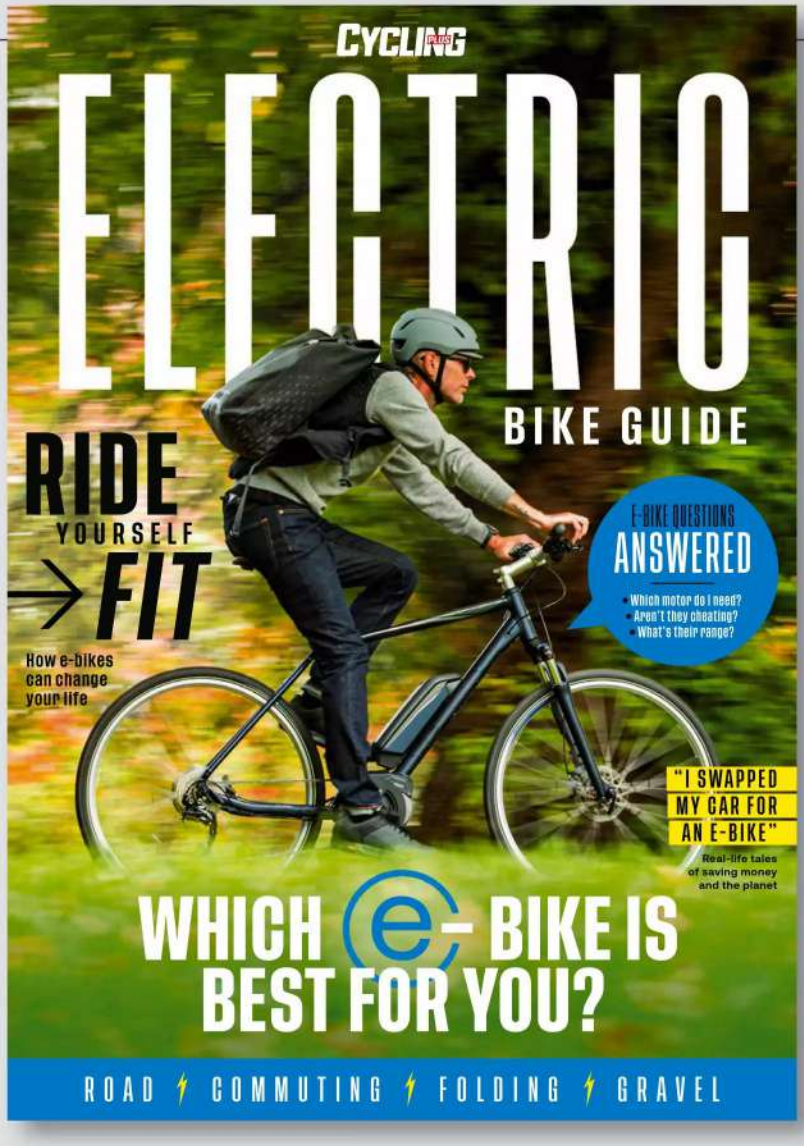
Everything you wanted to know about this important link between the brain and gut.

NEMO'S GARDEN

Scientists are plunging beneath the waves to grow terrestrial plants under the sea.

ON SALE 14 SEPT

SF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POPCORN SCIENCE

Are elves' long lives realistic?

What's the biology behind the elves' extended lifespans in *The Lord Of The Rings*?

by STEPHEN KELLY

The new *The Lord Of The Rings* TV show, *The Rings Of Power*, is a prequel set in the Second Age of Middle-earth, thousands of years before Frodo takes his long walk to Mordor. And yet, the show features familiar characters like Elrond and Galadriel, elves who were alive during the original *The Lord Of The Rings* trilogy. According to the lore of author J. R. R. Tolkien, this is because elven lifespans are tied to the fate of the Earth, effectively making them immortal. But this is not *BBC Magic Focus* you're reading. Surely there must be a biological reason for how elves manage to live so long, while we age, decay and die?

"There are many explanations for why we die," says evolutionary biologist Henry Gee, author of *The Science Of Middle-earth* and *A (Very) Short History Of Life On Earth*. "One is that the action of living generates harmful chemicals called free radicals." These, says Gee, are not tiny anarchists running around your body. "[They] are active fragments of metabolised food. So you eat your sandwich and it gets broken down into various things, but it also releases these free radicals that go around damaging DNA and so on." This leads to your tissues degrading as you get older, and increases the risks of mutations, such as cancer. "Your cells do renew, but because of free radicals this process of renewal becomes less effective as you get older," he says.

Different species live for different lengths of time. The tiny roundworm *Caenorhabditis elegans*, for example, rarely lives beyond three weeks. Your dog? It likely won't see its 15th birthday. But cold-blooded creatures such as tortoises can live for well over a century. The reasons for these varying lifespans can generally be put down to attributes like diet, physical size and the speed of their metabolism.

"Various experiments on animals like mice have shown that calorie restriction can prolong life," says Gee. "The elves have disgustingly healthy lifestyles. They're not like the dwarves, who are always feasting. They don't eat much, so they would not subject themselves to excessive amounts of free radicals. I would also imagine that they have very robust mechanisms to soak up free radicals in their metabolism, which not only helps prevent diseases associated with ageing, but also avoids tissue damage as they age."

According to Gee, another aspect that tends to affect lifespan is reproduction.

"Organisms that live fast and die young tend to have a lot of offspring," he says. "Creatures like rodents have a high-pressure life because they are constantly under the threat of predation. They need to reproduce as fast as possible if they want to maintain their species." Elves, meanwhile, only invest in a small number of children. They also live a relatively privileged, risk-free existence.

This all sounds attractive. We are, after all, restricted to a maximum lifespan of around 100. But Gee regards elven immortality as less of a gift, and more of a curse.

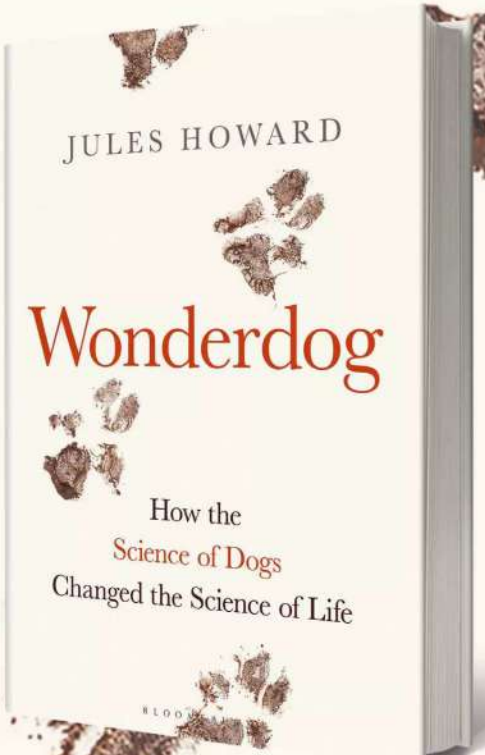
"I think immortality would be disastrous," he says. "Just imagine the boredom. One of the themes of *The Lord Of The Rings* is that only bad comes from wanting to prolong your life indefinitely. You can see that with Gollum. The elves themselves say that the gift of death to human beings is something that, as the ages progress, even the gods will envy." **SF**

VERDICT

Elves' disease-resistant biology and clean-living lifestyles help them on their way to immortality. We're unlikely to be able to catch up.

by STEPHEN KELLY (@StephenPKelly)
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE. MAIN ILLUSTRATION: JACOB STEAD



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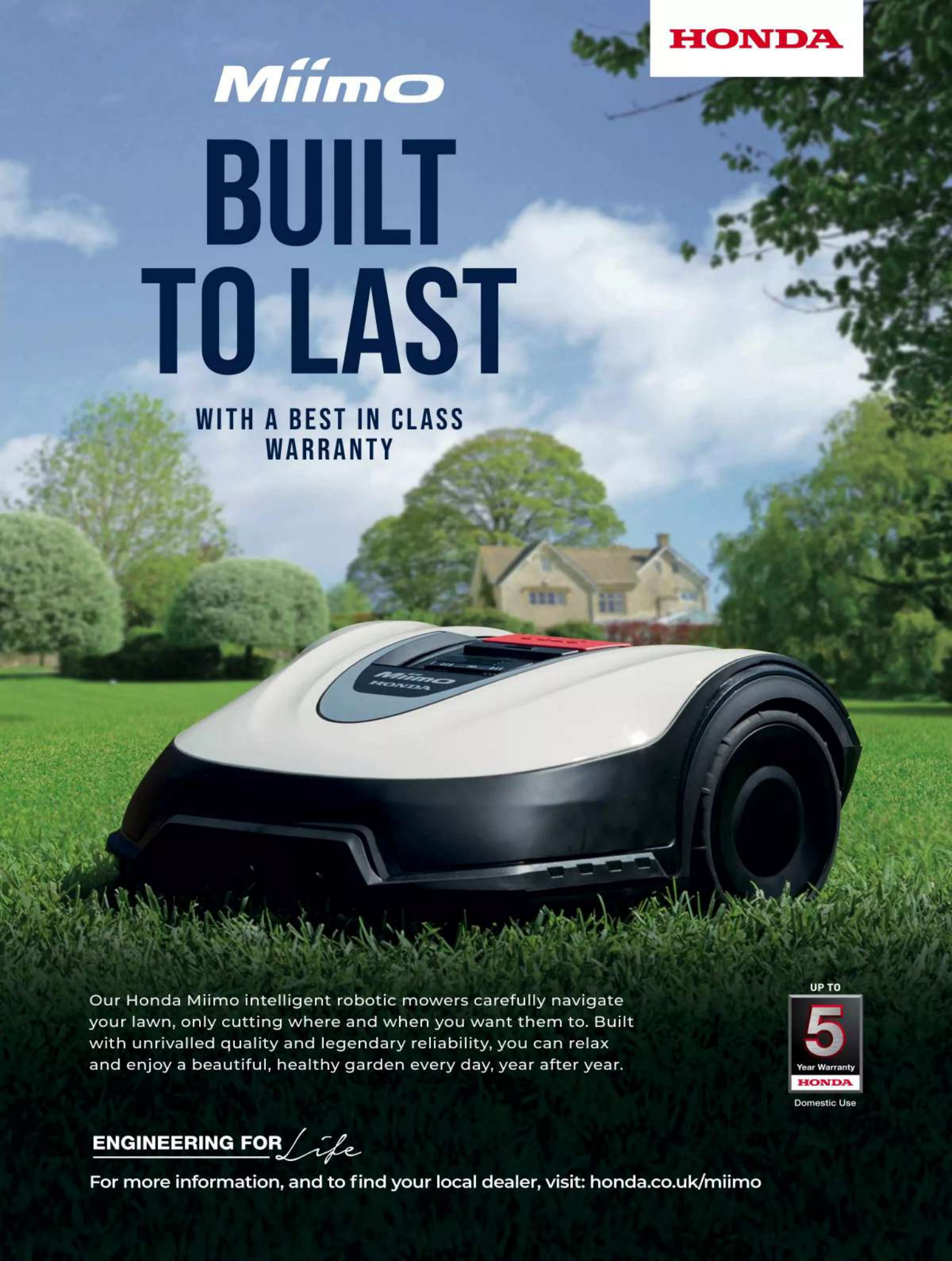

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